QUAIN'S ANATOMY

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QUAIN'S ANATOMY

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QUAIN'S
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ELEVENTH EDITION

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BY J. SYMINGTON

WITH 349 ILLUSTRATIONS

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PREFACE

THIS part of Quain's Anatomy deals with the topographical anatomy and the morphology of the digestive, respiratory, and genito-urinary systems, and of various bodies situated in the neck, thorax, and abdomen, which may be grouped together as ductless glands, or organs of internal secretion. The text has been thoroughly revised and in places rewritten. In addition, a large number of original illustrations have been added to the work—most of these have been drawn by Miss Alice M'Hinch. The chapter on the peritoneum has been written by Mr. P. T. Crymble, who has supplied many new figures for it. A number of drawings by the late Professor J. S. Dickey have been utilised in the account of the respiratory organs. The skiagrams of the teeth are from an Atlas by the Editor and Dr. Rankin. Acknowledgments are due to Dr. Christopher Addison, Professor W. M. Baldwin, Dr. W. L. H. Duckworth, Dr. H. P. Malcolm, Mr. J. Howard Mummery, and Mr. J. W. Thomson Walker for permission to use blocks. The proofs have been read and the index prepared by Miss M. E. Rea.

BELFAST:
May 1914.

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DIGESTIVE SYSTEM.

THE **digestive system** (*apparatus digestorius*) consists of the alimentary canal, the teeth, and various glands—the secretions of which are discharged through ducts opening into the canal.

The alimentary canal commences at the mouth and terminates at the anus. Its total length is, on an average, about 8 metres to 10 metres (25 to 30 feet).

The part situated in the head, neck, and thorax is comparatively straight, and measures from its commencement at the entrance into the mouth to its termination in the stomach about 37 cm. to 45 cm. (15 to 18 inches). The rest of the canal lies in the abdomen and pelvis. If this portion extended in a straight line from the œsophageal opening of the stomach to the anus, it would not exceed in length the part above the diaphragm: but in consequence of its convoluted and tortuous course, it is nearly twenty times as long.

The part of the alimentary canal which lies above the diaphragm consists of the *mouth, pharynx*, and *œsophagus*; while that contained in the abdomen and pelvis consists of the *stomach* and the *small* and *large intestines*. The mouth is partly bounded by certain bones of the skull—namely, the maxillæ and palate bones above and the mandible below. It is provided with special masticatory organs—the teeth—while the tongue forms a muscular elevation in its floor. The upper part of the pharynx is purely an air-passage, and communicates anteriorly with the two nasal cavities, and laterally, by the two auditory tubes, with the tympanic cavities. In its lower part, the larynx opens on its ventral wall between the mouth and the œsophagus. From the œsophagus to the anus, the alimentary canal is much simpler and more uniform in its structure. It forms a tube (**tubus digestorius**), the cavity of which is bounded from within outwards by a mucous membrane, a submucous layer, and a muscular coat. The stomach and intestines are partially provided, in addition, with an external serous coat derived from the peritoneum. Numerous small glands are situated in the wall of the alimentary canal, some in its mucous membrane, and others in its submucous tissue. The larger glands, the ducts of which open into the canal, are the *salivary glands*, the *liver*, and the *pancreas*. The ducts of the *salivary glands* open into the mouth, and those of the *liver* and *pancreas* into the upper part of the small intestine. Since the respiratory tract is developed in much the same way as a gland by an outgrowth from the ventral wall of the fore-gut and remains permanently connected with it, the alimentary canal and respiratory organs are often grouped together as the *gastro-pulmonary system*.

CAVUM ORIS.

The cavity of the mouth opens anteriorly on the face by a transverse aperture called the *rima oris*, while posteriorly it communicates with the pharynx through the fauces (*isthmus faucium*). When the lips are in contact, the oral aperture

is situated above the level of the line of contact of the teeth of the upper and lower jaws, and generally corresponds to the level of the middle of the crowns of the upper teeth as far outwards as the first premolars. The oral cavity is divided into two parts—an outer and inner—by the alveolar arches and teeth (see fig. 1).

The outer and smaller part (**vestibulum oris**) is horseshoe shaped, and is bounded externally by the lips and cheeks; internally by the teeth, and by the gums covering the outer aspect of the alveolar processes of the upper and lower jaws. The roof and floor of the vestibule are formed by the reflection of the mucous membrane of the lips and cheek inwards to the alveolar processes, these it joins

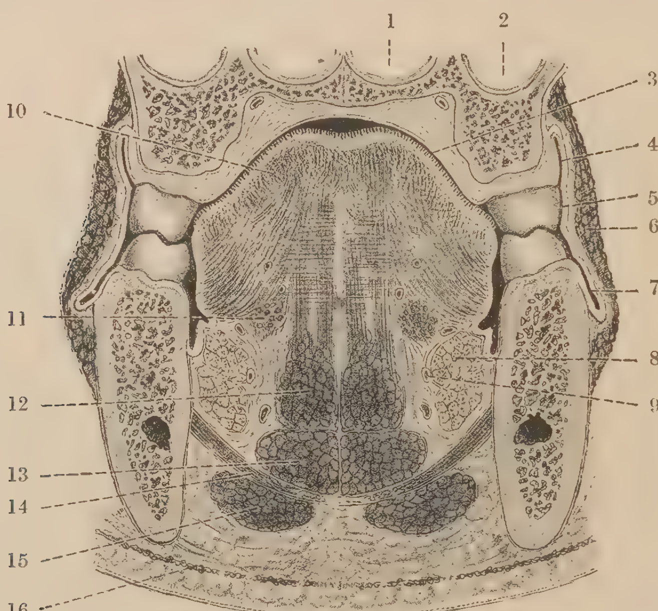


Fig. 1.—Coronal section of the mouth just behind the second molar teeth. Natural size. (J. Symington.)

1, nasal fossa; 2, maxillary sinus; 3, cavum oris proprium; 4, superior alveolo-labial sulcus; 5, vestibulum oris; 6, buccinator muscle; 7, inferior alveolo-labial sulcus; 8, sublingual gland; 9, duct of submandibular gland; 10, superior longitudinal muscle; 11, inferior longitudinal; 12, genio-glossus; 13, genio-hyoid; 14, mylo-hyoid; 15, anterior belly of digastric; 16, platysma.

about the level of the middle of the roots of the teeth. The extension of the vestibule upwards and downwards, external to the gums, may be called the *superior* and *inferior alveolo-labial sulci*. Each of these sulci is interrupted in the median plane by a small vertical fold of the mucous membrane called the *frenulum labii*. The fold connecting the upper lip with the gum is larger than that of the lower lip. The inferior sulcus tends to become gradually shallower as it passes backwards, until opposite the last molar tooth where the floor rises somewhat abruptly. The vestibule extends posteriorly to the level of the anterior border of the ramus of the mandible, lateral to which and extending forwards beyond the ramus is the masseter muscle (see fig. 3). It receives on each side the secretion of the parotid gland.

The inner portion of the mouth (**cavum oris proprium**) lies within the concavity of the alveolar and dental arches, and is bounded above by the hard palate, while in its floor is situated the anterior portion of the tongue. Behind, it communicates with the pharynx.

If the mouth is closed, the dorsum of the tongue is more or less accurately moulded to the palate, its tip and sides are in contact with the teeth, and the free part of the under-surface rests upon a horseshoe-shaped area of mucous membrane, which extends from the mandible to the tongue. This area is sometimes termed the floor of the mouth. In the median plane, the mucous membrane forms a vertical fold—the frenulum linguæ—and on each side of this fold there is a small conical elevation, at the apex of which is the orifice of the duct of the submandibular gland. Passing backwards and outwards from this elevation is a ridge, 2 cm. to 3 cm. in length, due to the sublingual gland, and on this ridge are the openings of small ducts from this gland. The cavity of the mouth is opened by the depression of the mandible and of the tongue.

When the teeth of the upper and lower jaws are in contact, the vestibule of the mouth communicates with the cavity of the mouth proper, merely by the narrow

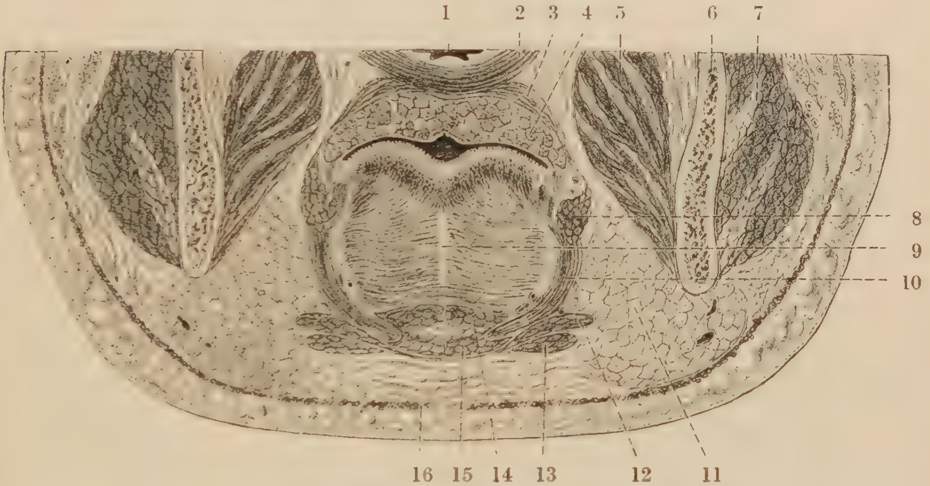


FIG. 2.—CORONAL SECTION OF THE POSTERIOR PART OF THE MOUTH, THE TONGUE, ETC. Two-thirds natural size. (J. Symington.)

1, pharynx; 2, levator palati; 3, palato-glossus; 4, glands of soft palate; 5, internal pterygoid; 6, ramus of lower jaw; 7, masseter; 8, stylo-glossus; 9, septum linguæ; 10, hyo-glossus; 11, submandibular gland; 12, mylo-hyoid; 13, digastric; 14, genio-glossus; 15, genio-hyoid; 16, platysma.

clefts between the teeth and by somewhat larger openings placed behind the last molar teeth and in front of the ramus of the jaw, but they communicate freely with one another when the mandible is depressed. The aperture on each side behind the last molars is bounded posteriorly by the mucous membrane passing inwards from the ramus of the jaw in front of the internal pterygoid muscle and the pterygo-mandibular raphe.

LABIA ORIS AND BUCCÆ.

The *lips* and *cheeks* are composed externally of skin, and internally of mucous membrane, between which are included muscles, vessels, and nerves, areolar tissue, fat, and numerous mucous glands.

The upper lip (**labium superius**) is continuous above with the nasal septum the posterior boundary of the nares and the alæ nasi; below, it ends in a free border. On each side, the naso-labial sulcus (see fig. 4), passing obliquely downwards and outwards from the ala of the nose towards the angle of the mouth, may be regarded as indicating the line of union of the upper lip with the cheek. Below the nasal

septum, the upper lip is marked by a shallow vertical depression—the *philtrum.* This median portion is probably developed from the fronto-nasal process, while the lateral parts are formed from the maxillary processes. The lower lip (**labium inferius**) does not show a similar division into a median and two lateral portions,

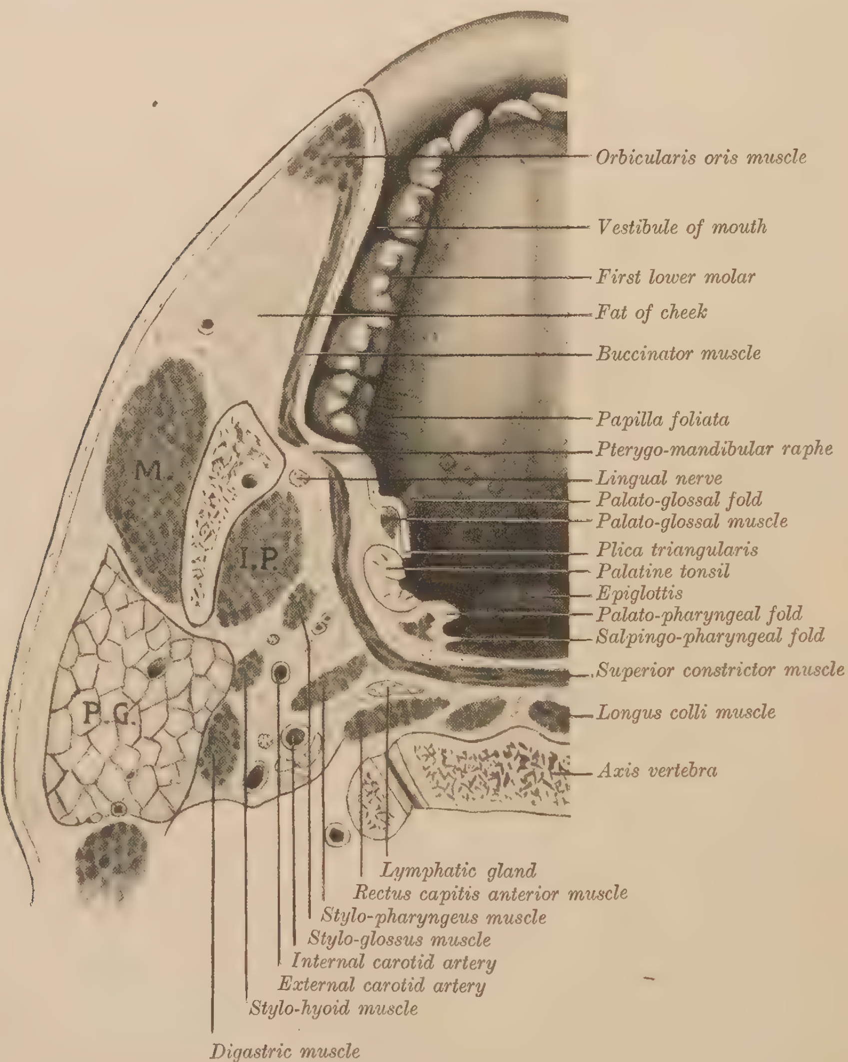


FIG. 3.—HORIZONTAL SECTION OF PART OF THE HEAD AT THE LEVEL OF THE ANGLE OF THE MOUTH, VIEWED FROM ABOVE. Natural size. (J. Symington.)

The tongue, which projected above the plane of the section, was not cut. P.G., parotid gland; M., masseter muscle; I.P., internal pterygoid muscle.

but it is separated from the mentum or chin by a transverse groove (*sulcus mento-labialis*).

The free borders of the lips consist of an anterior and a posterior portion. The anterior parts are not in contact, except when the oral aperture is firmly closed, but appear on the face as a dry, red, muco-cutaneous area, which is provided with numerous minute vascular papillæ and an abundant nerve-supply, so that it is highly sensitive. The posterior parts of the free borders of the lips, which meet

when the mouth is closed, are covered with a mucous membrane, kept moist by the secretion of well-developed submucous glands. The protrusion of the mouth in the negroid races is said to be largely due to the marked development of the mucous glands of their lips.

The layer of muscular fibres seen in sagittal sections of the lips and forming the orbicularis oris muscle extends to the junction of these two portions of the labial border, and then bending sharply forwards lies immediately beneath the dry muco-cutaneous membrane and ends at the union of this membrane with the skin.

The cheeks (**buccæ**) are continuous in front with the lips, and reach backwards to the masseter muscles. On their lateral or cutaneous aspect they possess no distinct upper or lower boundary, but internally they may be regarded as limited by the line of reflexion of the mucous membrane inwards on to the alveolar arches. The mucous membrane of the cheek, owing to its close attachment to the buccinator muscle, is either smooth or only slightly folded. The variations in the thickness of the cheek are almost entirely dependent upon the amount of fat situated between the skin and the buccinator muscle. During infancy, fat is especially abundant in this region, so that not infrequently the thickness of each cheek is nearly equal to the transverse diameter of the cavity of the mouth. In addition to the ordinary subcutaneous fat, there is a special lobule (*corpus adiposum buccæ*) provided with a well-defined capsule, situated in the posterior part of the cheek. This is often termed the sucking-pad, as it tends to prevent the cheeks being pressed inwards by the atmospheric pressure during sucking (see Symington, 'The Topographical Anatomy of the Child,' p. 14). The fat of the cheek is not only continuous with the adjacent subcutaneous fat, but it also extends upwards and backwards, internal to the masseter and temporal muscles, to gain the interval between the two pterygoid muscles.

FIG. 4.—VIEW OF THE LOWER PART OF THE FACE FROM THE FRONT. (J. Symington.)

Some small glands (*buccal glands*) lie between the buccinator muscle and the mucous membrane of the cheek. Two or three, larger than the rest, found between the masseter and buccinator muscles, and opening by separate ducts near the last molar teeth, are called the *molar glands*. The secretion of these glands is understood to be mucus; whether it has any of the specific properties of saliva is not known.

Immediately within the lips and cheeks are the *dental arches*, consisting of the teeth, gums, and alveolar borders of the jaws. The *gums* (*gingivæ*) are composed of dense connective tissue, cohering very closely with the periosteum of the alveolar processes, and covered by a red and highly vascular mucous membrane, which is smooth in its general surface, but is beset with fine papillæ in the immediate vicinity of the teeth.

Blood-vessels, lymphatics, and nerves of the cheek and lips.

Arteries.—The external maxillary artery passes across the cheek, in which the pulsations of the vessel can readily be felt. It supplies small twigs to the cheek, and there are also vessels entering the cheek from the buccinator branch of the internal maxillary artery. The lips are supplied by the superior and inferior labial branches of the external maxillary arteries. The labial arteries lie mainly in the submucous tissue, but occasionally are found embedded in the orbicularis oris muscle; they anastomose with the vessels of the opposite side.

The **veins** form plexuses: that at the free border of the lips being especially well marked. The blood is returned mainly by tributaries of the facial vein, but a few join the submental vein, and others communicate posteriorly with the pterygoid plexus.

The **lymphatics** of the lips are divisible into subcutaneous and submucous. The subcutaneous vessels of the lower lip pass downwards over the mandible, near the median plane, anastomose with those of the opposite side, and end in the submental glands. The other vessels from the lips pass backwards and downwards from near the angle of the mouth, and accompany the external maxillary artery to the lower border of the mandible, which they cross to enter the mandibular glands or pass on to some of the upper deep cervical glands. The lymphatics from the cheek accompany those of the upper lip, and have a similar termination. A few small lymphatic glands exist in the cheek near the angle of the mouth and also farther back in front of the masseter muscle.

Nerves.—The mucous membrane of the cheek is supplied by the buccinator branch of the mandibular nerve, and the skin mainly by branches of the auriculo-temporal nerve, which accompany the branches of the facial nerve (Frohse). The skin and the mucous membrane of the upper lip are supplied by the rami labiales superiores of the maxillary nerves, and the corresponding structures in the lower lip come from the rami labiales inferiores of the mental branch of the mandibular nerves. The facial is the motor nerve to the muscles of the cheek and lips.

LINGUA.

The **tongue** (*lingua*) is a muscular organ, situated in the floor of the mouth and in the anterior wall of the oral portion of the pharynx. It consists of a main portion or *body*, an anterior free extremity or *tip*, and a lower fixed part or *root*, which is attached to the lower jaw and hyoid bone. Its upper or dorsal surface, which is covered in its entire extent by mucous membrane, is convex from before backwards, and from side to side, with a slight median depression. This surface is in relation with the hard and soft palate, the palatine tonsils, the posterior wall of the pharynx, and the upper part of the anterior surface of the epiglottis (see fig. 13). The under-surface is free and covered with mucous membrane, in its anterior part only; the larger and posterior portion of this aspect not being free, but connected by various muscles with the lower jaw, hyoid bone, and styloid process. Here also enter its blood-vessels and nerves. The tongue has a free rounded border at its anterior extremity or tip, and at the sides as far back as the last molar teeth, where the lateral borders gradually disappears.

Mucous membrane.—On the under-surface of the tongue, the mucous membrane is smooth and thin, and in the middle line is raised into a prominent vertical fold, the *frenulum linguæ*. In front of the frenulum, the lingual vein can be distinctly seen on each side through the mucous membrane, and close to it lies the deep lingual artery. Farther out, a slight fold of the mucous membrane (*plica fimbriata*), with its free edge notched (see fig. 6), passes from near the tip backwards and outwards. This fold is better marked in the fetus and child than in the adult; and, according to Gegenbaur, it is a vestige of the under-tongue of the lemurs. From the under-surface of the tongue, the mucous membrane is reflected towards the inner aspect of the lower jaw. The deep groove between the tongue and the alveolar process of the jaw may be termed the *alveolo-lingual sulcus*.

The dorsal surface of the tongue (fig. 7), from its mode of development and the structure of its mucous membrane, presents a natural division into an anterior and

a posterior portion. The anterior part is developed in connexion with the inner aspect of the mandibular arch, and the posterior from the second and third arches. These two portions are frequently separated in the adult by a median pit—the

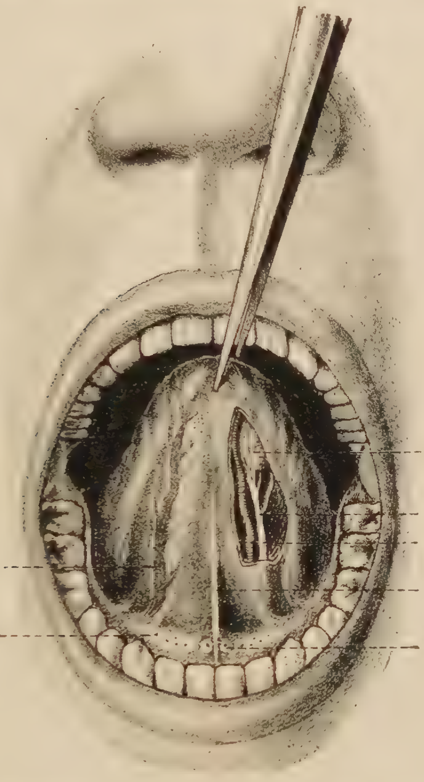


Fig. 5.—View of the under-surface of the anterior part of the tongue and of the sublingual portion of the floor of the mouth. (Modified from Testut.) (J. Symington.)

On the left side, part of the mucous membrane of the tongue has been removed, and also some fibres of the inferior lingualis muscle, in order to expose the deep lingual artery, the lingual nerve, and the gland of Blandin.

foramen cæcum—and a shallow groove (*sulcus terminalis linguæ*, His) passes from this outwards and forwards on each side to terminate in front of the lower end of the anterior palatine arch. The anterior portion, forming about two-thirds of the upper or dorsal surface, has its mucous membrane thin, closely adherent to the muscular tissue below, and provided with numerous small eminences named papillæ. These are also found upon the tip and borders, where, however, they gradually become smaller, and towards its under-surface they disappear. The mucous membrane on the posterior third of the tongue differs considerably from that covering its anterior two-thirds. It is thicker, smoother, and less adherent, and in place of papillæ, is studded with numerous mucous glands and lymphoid follicles. The latter are often called the *tonsilla lingualis*. Three folds of the mucous membrane—one median and two lateral—named the *glosso-epiglottic folds*, pass backwards from the base of the tongue to the epiglottis. Between these folds are the two

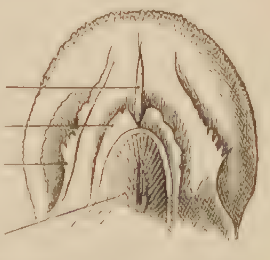


Fig. 6.—Under-surface of the tongue of a new-born child. (Gegenbaur.)

glosso-epiglottic fossæ or *sinuses*. Farther forward, the mucous membrane is joined on each side by the anterior palatine arch, behind which it is continuous with the mucous membrane covering the tonsils. Except in the neighbourhood of the vallate papillæ, the papillary surface of the tongue is devoid of glands, but they occur abundantly at the base, sides, and under-surface of the organ, and are in structure similar to those which occur elsewhere in the mouth.

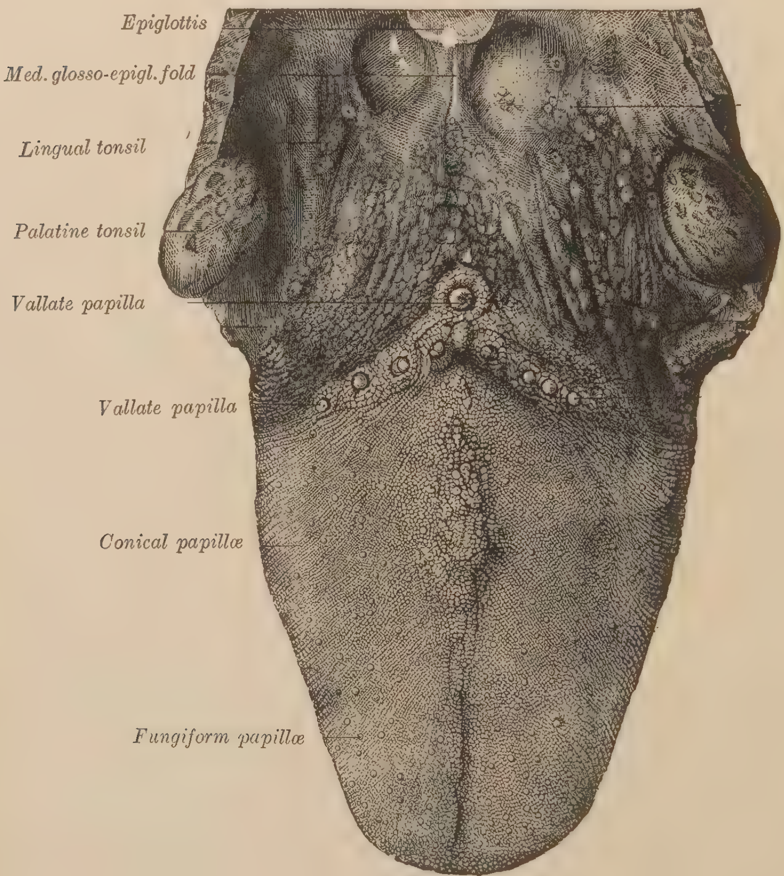


FIG. 7.—DORSAL SURFACE OF THE TONGUE AND PALATINE TONSILS. (Sappey.)

The **papillæ** found on the anterior two-thirds of the tongue are of four kinds: *vallate*, *fungiform*, *conical*, and *foliate*, varying both in size and form, but all of them visible to the naked eye; they themselves, like the rest of the mucous membrane of the tongue and mouth generally, are covered with closely set, microscopic secondary papillæ, hidden under the epithelium, which correspond with those of the skin, and are each occupied by a long loop of capillary blood-vessels. Lymphatics also originate within the papillæ, and pass, as elsewhere in the mouth, into a superficial plexus in the mucous membrane, from which again the lymph is conveyed away by valved vessels seated in the submucous tissue.

The vallate papillæ (fig. 7), from seven to twelve in number, are found at the union of the middle and posterior thirds of the tongue, arranged in two lateral rows, which run obliquely backwards and inwards towards a median papilla, like the arms of the letter V; but not infrequently there are two papillæ in the middle line.

These vallate papillæ are situated in cup-like depressions of the mucous membrane, and have the shape of a truncated cone, of which the smaller end is attached to the bottom of the cavity, and the broad flattened base appears on the surface (fig. 8). They are, therefore, surrounded by a circular trench (fossa), around which again is a slight annular elevation of the mucous membrane (vallum). In some of them there is found a central depression. The ducts of one or more serous glands open into the trench of each vallate papilla (fig. 8, *d*; fig. 9, *M*). The stratified epithelium covering each papilla vallata is thick, and completely conceals the minute secondary papillæ.

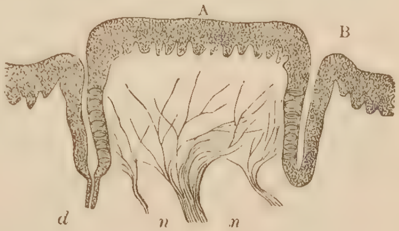


FIG. 8.—VERTICAL SECTION OF A VALLATE PAPILLA FROM THE CALF. 25 diameters. (Engelmann.)

A, the papilla; B, the surrounding wall. The figure shows the nerves, *n n*, of the papilla spreading towards the surface, and towards the taste-buds which are embedded in the epithelium at the sides; in the sulcus on the left, the duct, *d*, of a gland is seen to open.

Taste-buds are found forming a zone around the circumference of these papillæ; in man and some animals also upon the opposite walls of the valla (fig. 9).

The *fungiform papillæ*, more numerous than the last, are small rounded eminences scattered over the middle and fore-part of the dorsum of the tongue (fig. 7); but they are found in greater number and closer together at the apex and near the borders. They are easily distinguished in the living tongue owing to their deep-red colour. They are narrow at their points of attachment, but are gradually enlarged towards their free extremities, which are blunt and rounded.

FIG. 9.—SECTION OF VALLATE PAPILLA, HUMAN. THE FIGURE INCLUDES ONE SIDE OF THE PAPILLA AND THE ADJOINING PART OF THE VALLUM. Magnified 150 diameters. (Heitzmann.)

E, epithelium; *G*, taste-bud; *C*, corium with injected blood-vessels; *M*, gland with duct.

The *conical papillæ* are the most numerous of all, as well as the smallest. They are minute, conical, tapering, or cylindrical eminences, which are densely set over the greater part of the dorsum of the tongue (fig. 7), but towards the base gradually disappear. They are arranged in lines diverging from the raphe: at first in an oblique direction, like the two ranges of papillæ vallatæ, but gradually becoming transverse towards the tip of the tongue. At the sides, they are longer and more slender, and arranged in parallel rows, perpendicular to the border of the tongue. The papillæ, here described as conical, are sometimes divided into the conical and the filiform—the latter being the shorter and the smaller.

The papillary surface of the tongue is supplied abundantly with nerves, some of which terminate in end-bulbs, and a few in tactile corpuscles. In the fungiform papillæ the nerves are large and numerous; but they are still more abundant, and of greater size, in the vallate papillæ, where they are chiefly distributed in the neighbourhood of the taste-buds (fig. 8).

The papillæ, besides being the parts chiefly concerned in the special sense of taste, also possess, in a very acute degree, tactile sensibility ; and the conical and filiform papillæ, armed with their denser epithelial covering, serve a mechanical purpose, in the action of the tongue upon the food, as is well illustrated by the more developed form which these papillæ attain in many carnivorous animals.

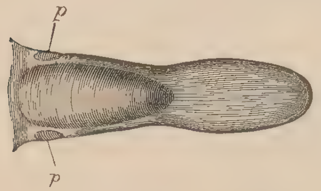


FIG. 10.—TONGUE OF RABBIT, SHOWING THE SITUATION OF THE PAPILLÆ FOLIATÆ, *p*.

The two *papillæ foliatæ* consist of a variable number of small vertical transverse folds present on each side of the tongue. These folds commence just in front of the attachment of the anterior palatine arch and extend forwards for a variable distance along the lateral border of the tongue, gradually becoming less distinct.

In some animals (*e.g.*, rabbit), there is present on each side of the tongue, nearly opposite the ends of the V formed by the line of papillæ vallatæ, an oval aggregation of transversely placed ridges or laminæ with intervening furrows, which is termed the *papilla foliata* (fig. 10). The ridges are covered with a thick stratified epithelium, and in this epithelium, at their sides, are embedded numerous taste-buds. The papillæ foliatæ are more distinctly defined in the rabbit than in man.

Foramen cæcum and thyro-glossal duct.—The foramen cæcum is a median recess, variable in size and sometimes absent, which is situated just behind the median vallate papilla. According to His, it represents the apex of a V-shaped depression, which is formed by the development of the tongue from an anterior median process (tuberculum impar), and two lateral and posterior prominences, which grow forwards at the sides of the tuberculum impar. According to the same authority, the foramen cæcum indicates the position of the epithelial outgrowth from which the median portion of the thyroid gland has been formed. As the thyroid recedes from the tongue, it becomes connected with the foramen cæcum by a long narrow tube—the *thyro-glossal duct*. The upper part of this duct may persist as a canal (*ductus lingualis*) leading from the foramen cæcum downwards to the hyoid bone.

Glands.—The mucous membrane of the tongue is provided with numerous small glands (*lingual glands*), collected principally about the posterior part of its upper surface, near the papillæ vallatæ and foramen cæcum, into which last the ducts of several glands open. These glands have usually been supposed to secrete mucus, but it has been ascertained that some of them—especially those which open in the trenches around the papillæ vallatæ, and at other parts where taste-buds occur—yield a serous secretion (Ebner). Other small glands are found also beneath the mucous membrane of the borders of the tongue. There is, in particular, a group on the under-surface of the tongue, on each side near the apex, called the anterior lingual glands or *glands of Nuhn-Blandin* (see fig. 5). They are there aggregated into a small oblong mass, out of which several ducts proceed and open in a line on the mucous membrane. Most of the glands are acino-tubular.

The mucous membrane of the tongue—at least its posterior part—contains a large amount of lymphoid tissue, which is collected at numerous points into the denser nodular masses known as follicular glands, or lymphoid follicles. The blood-vessels and lymphatics of this part of the membrane are numerous and large, but the papillæ on its surface are comparatively small, and are completely concealed by the thick superjacent epithelium. Here and there, the mucous membrane exhibits recesses or crypts (fig. 7), either simple or surrounded by smaller ones which open into them. The walls of these recesses are generally studded with lymphoid nodules ; and they receive many of the ducts of the mucous glands.

Muscular substance.—The muscular floor of the mouth is formed by the two mylo-hyoid muscles with the two genio-hyoids on their upper aspect; and the substance of the tongue is mainly composed of muscular fibres situated above and behind the floor. The lingual muscles are divided into the extrinsic and the intrinsic: the former arising from structures outside the tongue and passing into its substance to be inserted by blending or interlacing with other muscles; the latter are placed entirely within the organ.

The two largest extrinsic muscles—genio-glossi—connect the tongue with the anterior part of the mandible; their fibres enter from below, and, becoming fan-shaped, radiate in its substance from its tip backwards as far as the hyoid bone. Another pair of muscles—hyo-glossi—arise on each side from the body and cornua of the hyoid bone and pass upwards to the tongue, forming the posterior part of its lateral wall. The two genio-glossi lie in close contact with one another,

Fig. 11.—Longitudinal vertical section of the tongue, lip, etc. (Kölliker and Arnold.)

m, symphysis of the lower jaw; *d*, incisor tooth; *h*, hyoid bone; *g.h.*, genio-hyoid muscle; *g*, genio-glossus spreading along the whole of the tongue; *tr*, transverse muscle; *l s*, superior longitudinal muscle; *gl.*, lingual glands; *f*, lymphoid crypts; *e*, epiglottis; *l*, section of the lip with its labial glands; *o*, cut fibres of the orbicularis oris; *l.m.*, levator menti.

whereas the hyo-glossi are separated by nearly the entire breadth of the base of the tongue. Each stylo-glossus proceeds from its styloid process, forwards and downwards, and joins the tongue along the upper border of the hyo-glossus, while the small palato-glossus descends in the palato-glossal arch from the soft palate to the side of the tongue. The mylo-hyoid muscle ends in a free posterior border anterior to the base of the tongue, and a space is left external to the hyo-glossus and behind the mylo-hyoid by which the lingual and hypoglossal nerves, the lingual vein, and a process of the submandibular gland and its duct reach the side of the tongue; the connective tissue of the floor of the mouth becomes continuous with that of the neck. The lingual artery and the glosso-pharyngeal nerve, however, enter the tongue on the median side of the hyo-glossus muscle.

The intrinsic or proper muscles of the tongue will be noticed here particularly; but the extrinsic will be described in detail under the muscular system. The intrinsic muscles are as follows:—

The **superior longitudinal muscle** consists mainly of longitudinal fibres, placed near the upper surface of the tongue, immediately beneath the mucous membrane, and is traceable from the apex of the organ backwards to the hyoid bone (fig. 11, *l s*; fig. 12). The individual fibres do not run the whole of this

distance, but are attached at intervals to the submucous and glandular tissues. The entire layer becomes thinner towards the base of the tongue, near which it is overlapped at the sides by a thin plane of oblique or nearly transverse fibres derived from the palato-glossus and hyo-glossus muscles.

The **inferior longitudinal muscle** consists of a rounded muscular band, extending along the under-surface of the tongue from base to apex, and lying outside the genio-glossus, between that muscle and the hyo-glossus (fig. 12). Posteriorly, some of its fibres are lost in the substance of the tongue, and others are said to reach the hyoid bone, but Parsons[1] did not find such an attachment. In front, having first been joined, at the anterior border of the hyo-glossus muscle, by fibres from the stylo-glossus, it is prolonged beneath the border of the tongue as far as its point.

The **transverse** muscular fibres of the tongue (fig. 11, *tr*; fig. 12) form, together with the intermixed fat, a considerable part of its substance. They are

FIG. 12.—CORONAL SECTION OF THE TONGUE ABOUT THE MIDDLE OF ITS LENGTH, LEFT HALF SEEN FROM BEHIND. (W. Krause.)

found in the interval between the upper and lower longitudinal muscles, and they are interwoven extensively with the other muscular fibres. Passing outwards from the median plane, where they take origin from a fibrous septum (fig. 12), they reach the dorsum and borders of the tongue. In proceeding outwards, they separate, and the superior fibres incline upwards, forming a series of curves, with the concavity upwards. The fibres of the palato-glossus muscle are stated by Zaglas and Henle to be continuous with fibres of the transverse set.

Vertical muscles (external perpendicular muscle of Zaglas), decussating with the transverse fibres and the insertions of the genio-glossus (fig. 12), form a set

[1] 'Topography and Morphology of the Human Hyoid Bone,' *Jour. Anat. and Phys.*, vol. xliii., 1909.

FIG. 13.—MEDIAN SECTION OF THE HEAD AND NECK. Two-thirds natural size. (Braune.)

1, sphenoidal sinus; 2, lateral recess of pharynx; 3, pharyngeal orifice of tuba auditiva; 4, anterior arch of atlas; 5, soft palate; 6, body of axis; 7, oral portion of pharynx; 8, epiglottis; 9, arytenoid muscle; 10, cricoid cartilage; 11, trachea; 12, œsophagus; 13, origin of innominate artery from aorta; 14, genio-glossus muscle; 15, genio-hyoid muscle; 16, mylo-hyoid muscle; 17, platysma; 18, hyoid bone; 19, thyroid cartilage; 20, cricoid cartilage; 21, isthmus of thyroid body; 22, sterno-hyoid; 23, sterno-thyroid; 24, left innominate vein; 25, manubrium sterni.

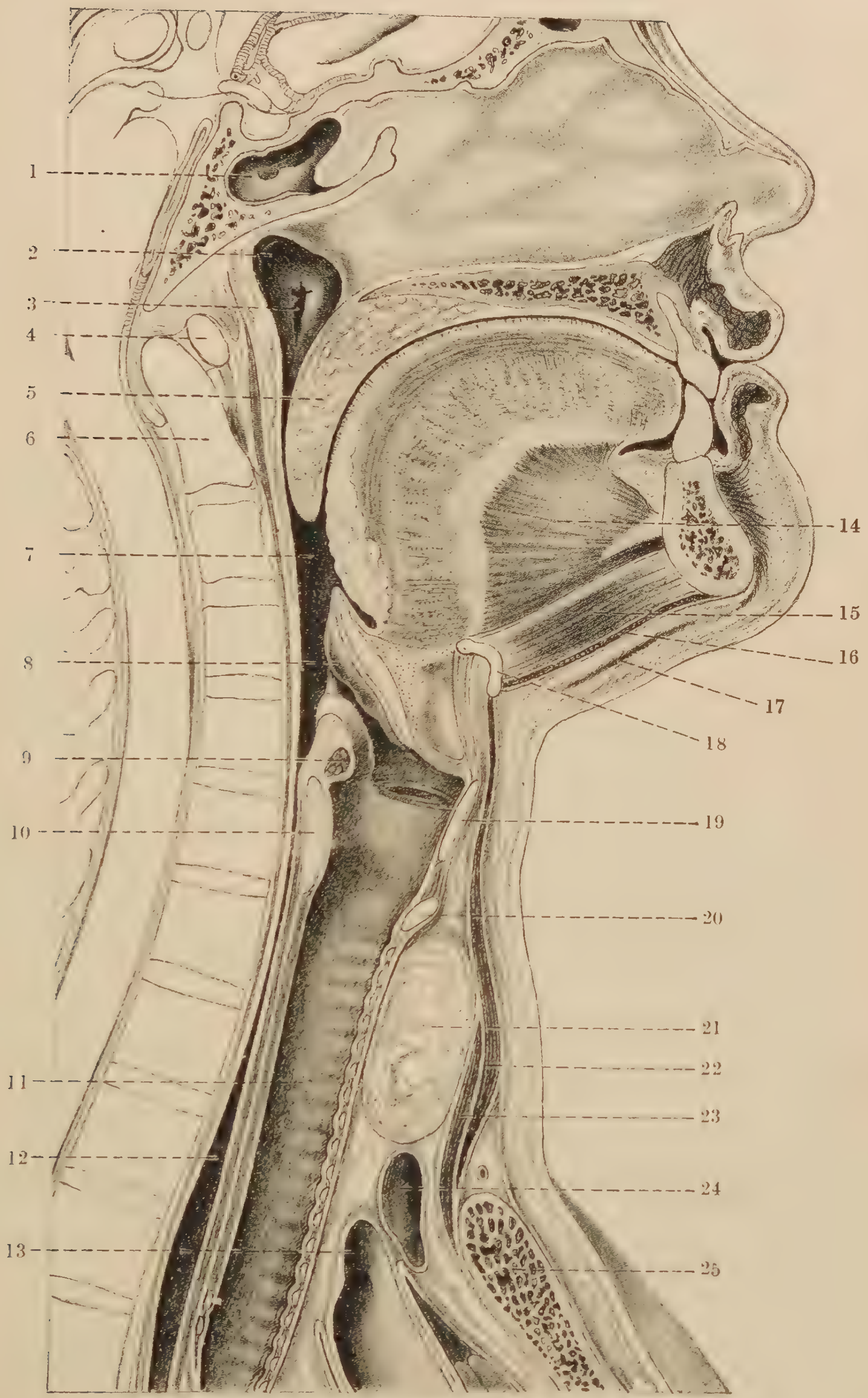


Fig. 13.

of curves in each half of the tongue, with their concavity outwards, and extending down and out from the dorsum to the under-surface of the border, so that those which are outermost are shortest.

Examined in transverse sections, the muscular fibres are seen to be arranged so as to render the substance divisible into an outer part or *cortex* and an internal or *medullary part.* The fibres of the cortex are principally longitudinal, derived superiorly from the superior longitudinal, farther outwards from the hyo-glossus, on the side from the stylo-glossus, and beneath this from the inferior longitudinal. They ensheath the medullary part on all sides except inferiorly, where the genio-glossi muscles enter it between the inferior linguales. In the medullary part are found, embedded in fat, the decussating fibres of the transverse muscle passing across, the genio-glossi radiating upwards and outwards, and the vertical muscles arching downwards and outwards. In addition to the movements which may be given to the tongue by the extrinsic muscles, this organ is capable of being curved upwards, downwards, or laterally by its cortical fibres, it is flattened by the vertical fibres, and its margins are again drawn together by the transverse, whilst the two last mentioned, acting together, would tend to lengthen the organ.

The **septum** of the tongue is a thin fibrous partition which extends forward from the hyoid bone to the tip, and divides one half of the medullary part of the tongue from the other, but does not penetrate into the cortex.

Blood-vessels, lymphatics, and nerves.—The **arteries** of the tongue are derived from the lingual, with some small branches from the external maxillary and ascending pharyngeal. The **veins** empty their contents into the internal jugular trunk.

Lymphatics.—The lymphatic vessels of the tongue may be divided into three groups: anterior, posterior, and lateral. The anterior consist of a few vessels from the tip of the tongue, which pass downwards through the mylo-hyoid muscle to the submental glands situated between the anterior bellies of the digastric muscles. The posterior arise from the posterior part of the tongue in the neighbourhood of the vallate papillæ and are connected with those coming from the palatine tonsils. They pass down with the dorsal branches of the lingual artery, and then with the trunk of the lingual to end in the deep cervical glands. The lateral vessels run beside the sublingual gland; some of them pierce the mylo-hyoid muscle and end in the paramandibular glands, while others follow the lingual artery to the deep cervical glands.

The **nerves** of the tongue (exclusive of branches from the sympathetic nerves) are five—namely: the *lingual* branch of the trifacial, which supplies the papillæ and mucous membrane of the fore-part and sides of the tongue to the extent of about two-thirds of its surface with common sensibility; the *chorda tympani*, a branch of the facial nerve which accompanies the lingual to the tongue and probably serves as the nerve of taste to a corresponding area of the mucous membrane; the lingual branch of the *glosso-pharyngeal*, which sends filaments, both sensory and gustatory, to the mucous membrane at the base of the tongue, and especially to the papillæ vallatæ; the *superior laryngeal*, which distributes a few sensory branches in the neighbourhood of the epiglottis; and lastly, the *hypoglossal* nerve, which is distributed to the muscles both intrinsic and extrinsic. Microscopic ganglia exist upon the expansions of the glosso-pharyngeal nerve—especially in the neighbourhood of the papillæ vallatæ and papillæ foliatæ—and they have also been found in the sheep and calf upon the lingual nerve.

PALATUM.

The roof of the mouth is formed by the palate, which consists of two portions: the fore-part being named the hard palate and the back-part the soft palate. As a whole, the palate is concave from before backwards, and also from side to side.

The **hard palate** (*palatum durum*) is bounded in front and at the sides by the alveolar arches and gums, and is distinguished from the soft palate by having an osseous framework. It is covered by periosteum and mucous membrane—these two structures being firmly connected together. In front, the mucous membrane is thick, dense, rather pale, and corrugated, but it becomes thinner, smoother, and of a deeper colour behind. The corrugations of the mucous membrane—*palatal rugæ*—may be divided into the longitudinal and the transverse. In the middle line there is a longitudinal ridge or raphe, ending behind the interval between the two median incisors in a small eminence—the *papilla palatina* or *incisive pad*. This papilla corresponds to the anterior palatine fossa, and receives the terminal filaments

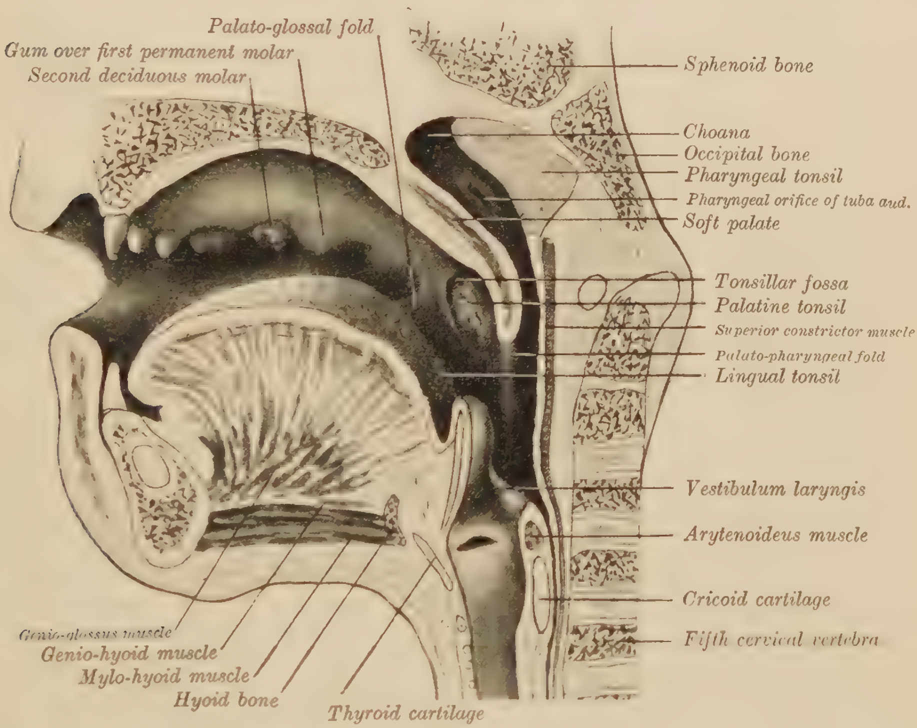


Fig. 14.—Median section of the mouth, pharynx, larynx, etc., of a boy aged three years. Mandible depressed. Natural size. (J. Symington.)

of the naso-palatine and anterior palatine nerves. Two small blind recesses, one on either side, are sometimes found upon it. They represent the lower part of the naso-palatine foramina or canals of Stensen, which in many animals lead from the mouth into the nasal cavities. The transverse rugæ, generally about five or six in number, vary considerably in their development. They are best marked during fetal life, and tend to become gradually less distinct and more irregular as age advances. In the adult, the ridges are often broken up into several small eminences and may even entirely disappear. G. Retzius has shown that these folds may present considerable variation in their degree of development and in their arrangement in fetuses of the same age.

Palatine folds are present in nearly all mammals, but reach their highest development in the ungulates and in certain whales. They may assist the young in holding on to the nipple, help in the trituration of food, or act as a water-strainer ;

but in man, they are evidently rudimentary structures (see C. Gegenbaur, 'Die Gaumenfalten des Menschen,' *Morph. Jahrb.*, Bd. iv., 1879; and G. Retzius, 'Die Gaumenfalten des Menschen und der Tiere,' *Biol. Untersuch.*, Bd. xiii., 1906).

The **soft palate** (*palatum molle* or *velum palatinum*) is formed by a duplication of mucous membrane, including muscular fibres and numerous glands. It extends from the hard palate, backwards and downwards, between the nasal and oral portions of the pharynx, and ends below in a free border, which in the middle is prolonged as a conical process—the uvula—while at the sides it is continuous with the palato-pharyngeal arches. As a rule, it is about 10 mm. to 12 mm. in thickness, nearly half of which is due to the glandular tissue situated between the muscles and the mucous membrane of the anterior or under-surface of the velum. This membrane, which is visible from the mouth, is thinner and redder than that of the hard palate, but, like it, is covered with a scaly stratified epithelium. The median ridge or raphe, which is continued backwards from the hard palate to the base of the uvula, indicates the original separation of the palate into two lateral halves. The posterior or upper surface of the soft palate is convex and continuous in front with the floor of the nasal fossæ. This surface is covered with ciliated columnar epithelium, while on the under-aspect and free margin the epithelium is scaly and stratified.

FIG. 15.—VIEW OF THE SOFT PALATE AND ISTHMUS FAUCIUM FROM BEFORE. (J. Symington.)

1, soft palate; 2, its raphe; 3, uvula; 4, palato-glossal arch; 5, palato-pharyngeal arch; 6, tonsil; 7, posterior wall of pharynx; 8, dorsum of tongue.

On both surfaces of the velum are found numerous small compound glands. They particularly abound on the under-surface, where they form almost a complete layer under the mucous membrane; they are also very abundant in the uvula.

The blood-vessels, lymphatics, and nerves of the palate.—The **arterial** supply of the palate is mainly derived from the descending palatine branches of the internal maxillary, which reach the palate on each side by the pterygo-palatine canal. In front, small twigs of the spheno-palatine artery pass through the anterior palatine foramen. The **veins** communicate behind through the pterygo-palatine canal with the pterygoid plexus, and in front by means of the anterior palatine foramen with the veins of the nose.

The **lymphatics** of the under-surface of the palate form a plexus which communicates with that of the opposite side and with the vessels of the gums. The vessels, joined posteriorly with those from the palatine tonsil, pass outwards through the pharyngeal wall and end in the deep cervical glands. The lymphatic vessels of the upper-surface of the soft palate are continuous with those in the floor of the nose. They descend in the side wall of the soft palate and join those on the under-surface in the neighbourhood of the palatine tonsil.

The sensory **nerves** of the palate (anterior, middle, and posterior palatine, and the naso-palatine) come from the maxillary division of the fifth nerve through the spheno-palatine ganglion. It is probable, however, that some fibres may come from the facial nerve through its great superficial petrosal branch, which forms one of the roots of the spheno-palatine ganglion. The palato-glossus muscle is supplied by the hypoglossal nerve, the tensor palati by the mandibular division of the fifth, and the levator palati and azygos uvulæ probably by the accessory nerve through the pharyngeal plexus, but some authorities derive the nerve-supply of these two muscles from the facial nerve.

GLANDULÆ SALIVALES.

The saliva, which is poured into the mouth, and there mixed with the food during mastication, is secreted by three pairs of glands, named from their respective

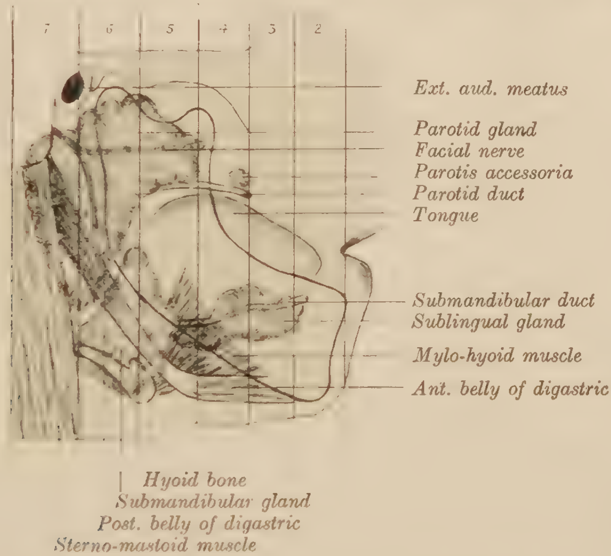


FIG. 16.—LATERAL VIEW OF THE SALIVARY GLANDS, ETC., RECONSTRUCTED FROM THE SERIES OF CORONAL SECTIONS OF A FEMALE, AGED FIFTY-FIVE YEARS, SHOWN IN FIGS. 17 TO 21. Half natural size. (J. Symington.)

Numbers 2 to 7 on the figure indicate the slabs into which the head was divided opposite the salivary glands, and the vertical lines between them show the position of the cuts.

situations—*parotid*, *submandibular*, and *sublingual*. Agreeing in their general physical characters and structure, these glands differ in their size, form, and position.

Glandula parotis.—The parotid (fig. 16) is the largest of the three salivary glands. It lies on the side of the face, in front of and below the ear, and extends as the processus mandibularis, deeply into the space behind the ramus of the lower jaw. Its weight varies from 20 grm. to 30 grm. Its greatest vertical extent is about 6 cm., its antero-posterior 4 cm. to 5 cm., and it reaches inwards for 2·5 cm. to 3 cm.

This gland forms an irregular wedge-shaped mass, with its base external and subcutaneous, while a median border, projecting inwards behind the level of the ramus of the jaw, divides the deep or median surface of the gland into an antero-median and a postero-median portion. When the hardened gland is removed entire, its median surface exhibits numerous markings due to its being moulded upon an irregular area formed by various bones, muscles, and blood-vessels.

Its *subcutaneous* or *lateral* surface is convex and lobulated, and is covered by

the skin and fascia, and partially by the platysma muscle. It is bounded above by the zygoma; below, by a line drawn backwards from the angle of the jaw to the sterno-mastoid muscle; and behind by the external meatus of the ear, the mastoid process, and sterno-mastoid muscle. Its anterior border, which lies over the ramus

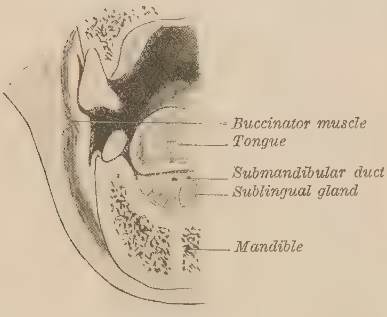


FIG. 17.—CORONAL SECTION OF FEMALE AGED FIFTY-FIVE YEARS, ANTERIOR SURFACE OF SLAB 3. Half natural size. (J. Symington.)

For position of section, see vertical line between 2 and 3 in fig. 16.

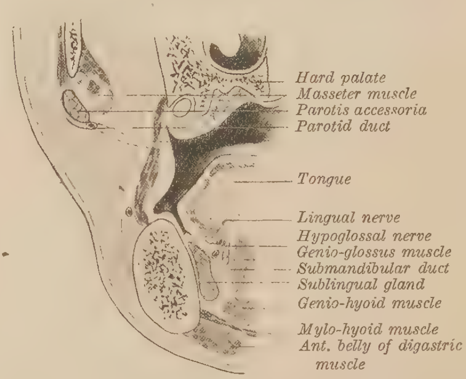


FIG. 18.—CORONAL SECTION OF FEMALE AGED FIFTY-FIVE YEARS, ANTERIOR SURFACE OF SLAB 4. Half natural size. (J. Symington.)

For position of section, see vertical line between 3 and 4 in fig. 16.

of the lower jaw, is irregular, and stretches forwards to a variable extent on the upper and posterior part of the lateral surface of the masseter muscle. It is from this anterior border of the gland that the duct passes off; and there is frequently found in connection with the duct, and lying upon the masseter muscle, a small process or a separated portion of the gland, which is called *glandula parotis accessoria.*

Postero-median surface.—The outer part of this surface exhibits a vertical groove where the gland is moulded over the anterior borders of the mastoid process and the sterno-mastoid muscle, the depth of the groove depending on the extent to which the gland passes backwards on the median and lateral aspects of these structures. Just above this area, the gland is in close contact with the cartilaginous floor of the external auditory meatus and the outer and lower part of the tympanic plate (see fig. 21). Internal to the mastoid groove, a shallow depression, passing downwards and forwards, is occupied by the posterior belly of the digastric muscle, and, still farther inwards, the gland is grooved by the styloid process and the stylo-hyoid muscle. The portion of the gland between the digastric and the styloid grooves comes into close relation with the outer surface of the internal jugular vein, and just behind this it reaches nearly to the stylo-mastoid foramen and is pierced by the facial nerve. Above and in front of the stylo-hyoid muscle the deep part of the gland sometimes reaches the internal carotid artery. The posterior auricular artery ascends in contact with the outer part of this surface.

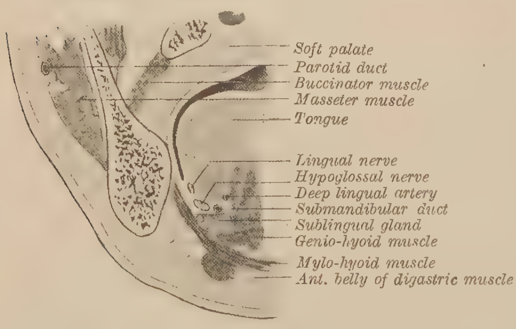


FIG. 19.—CORONAL SECTION OF FEMALE AGED FIFTY-FIVE YEARS, ANTERIOR SURFACE OF SLAB 5. Half natural size. (J. Symington.)

For position of section, see vertical line between 4 and 5 in fig. 16.

The *antero-median surface* of the gland (see fig. 23) possesses a well-defined vertical groove, in which is lodged the posterior borders of the ascending ramus of the jaw, the masseter, and the internal pterygoid muscles. The large mass of gland substance external to this groove turns forwards on to the lateral surface of

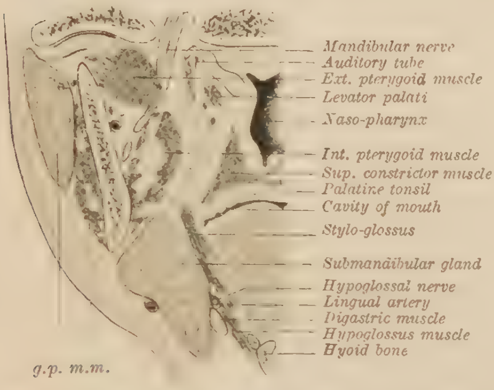


FIG. 20.—CORONAL SECTION OF FEMALE AGED FIFTY-FIVE YEARS, ANTERIOR SURFACE OF SLAB 6. Half natural size. (J. Symington.)

For position of section, see vertical line between 5 and 6 in fig. 16. *g.p.*, parotid gland; *m.m.*, masseter muscle.

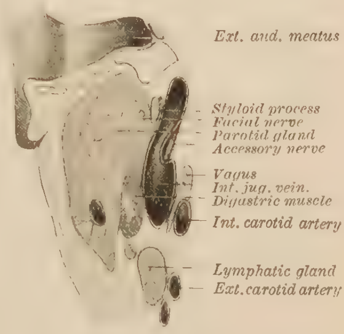


FIG. 21.—CORONAL SECTION OF FEMALE AGED FIFTY-FIVE YEARS, ANTERIOR SURFACE OF SLAB 7. Half natural size. (J. Symington.)

For position of section, see vertical line between 6 and 7 in fig. 16.

the masseter muscle, while that internal to the bone sends a small process (pterygoid) forwards on the median side of the internal pterygoid muscle and of the spheno-mandibular ligament.

The median border (see figs. 23 and 25) lies between the styloid muscles and the internal pterygoid muscle. It is sometimes termed the pharyngeal process,

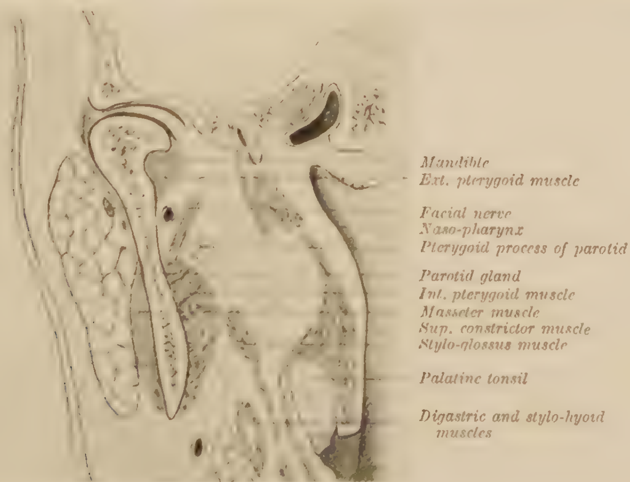


FIG. 22.—CORONAL SECTION OF THE HEAD OF AN ADULT FEMALE, PASSING THROUGH THE TEMPORO-MANDIBULAR ARTICULATION, VIEWED FROM THE FRONT. Two-thirds natural size. (J. Symington.)

although it is separated by a considerable space—occupied by loose connective tissue—from the side wall of the pharynx.

The external carotid artery, after passing upwards internal to the posterior belly of the digastric and the stylo-hyoid muscles, turns outwards and enters the

deep surface of the gland close to its median border. After a short course in the gland, the artery divides into temporal and internal maxillary, the temporal branch ascends between the gland and the jaw and appears above the gland in front of

FIG. 23.—SAME SECTION AS FIG. 22, WITH POSTERIOR PART OF MANDIBLE AND ATTACHMENTS TO IT OF THE EXT. AND INT. PTERYGOID AND MASSETER MUSCLES REMOVED.
Two-thirds natural size. (J. Symington.)

the ear, and the internal maxillary branch leaves the gland almost immediately after its origin and passes forwards between the neck of the condyle and the spheno-mandibular ligament. The internal carotid artery is only occasionally in contact with a small process of the gland, being separated from it by the styloid process,

FIG. 24.—HORIZONTAL SECTION OF THE HEAD OF A MAN AGED FORTY YEARS, AT THE LEVEL OF THE NECK OF THE CONDYLE OF THE MANDIBLE, VIEWED FROM ABOVE.
Two-thirds natural size. (J. Symington.)

The parotid gland is seen external to the neck of the condyle, and turning backwards and inwards between the neck of the condyle and the mastoid process. The fibres passing backwards and outwards from the outer surface of the external pterygoid plate to the neck of the condyle belong to the external pterygoid muscle.

the styloid and digastric muscles, and the internal jugular vein. As already explained, the parotid gland comes into close relation with the internal jugular vein for a short distance above the digastric muscle. The temporal and maxillary

veins unite in the gland, and the resulting venous trunk leaves the gland near the angle of the jaw.

The facial nerve enters the gland near the stylo-mastoid foramen, and passes forwards and outwards towards the posterior border of the mandible, and near the neck of the condyle divides into its two main divisions—temporo-facial and cervico-facial—and these give off numerous communicating branches which emerge from the gland at its upper, anterior, and lower borders. The main trunk and its various subdivisions in their course through the gland lie near its deep surface. Branches of the great auricular nerve pierce the gland, while the auriculo-temporal

FIG. 25.—HORIZONTAL SECTION OF HEAD OF SAME SUBJECT AS SHOWN IN FIG. 24, BUT 16 MM. LOWER, VIEWED FROM ABOVE. Two-thirds natural size. (J. Symington.)

nerve ascends beneath its upper and posterior part. The glosso-pharyngeal and vagus nerves are not in actual contact with the gland, and the accessory nerve only occasionally, so that the only cerebral nerve in close relation to it is the facial.

The following are recent papers on the shape and relations of the salivary glands: Parsons, 'On the Form of Parotid Gland.' *Jour. Anat. and Phys.*, vol. xlv., April 1911; Symington. 'The Topographical Anatomy of the Salivary Glands,' *Ibid.*, vol. xlvi., Jan. 1912: Jefferson and Platt, 'The Parotid Gland,' *Anat. Anzeiger*, Bd. xliii., April 1912.

The development and comparative anatomy of the salivary glands is described and well illustrated by Carmalt, Huntington and Schulte, in *Contributions to the Anatomy and Development of the Salivary Glands in the Mammalia*, Columbia University Press, 1913.

The capsule of the parotid is continuous with the fibrous framework, which traverses the gland in all directions and unites its lobules together. This capsule is best developed on the subcutaneous surface. It unites the gland firmly to the mastoid process and to the cartilage of the external auditory meatus, but in most other situations it is connected with adjacent structures by loose areolar tissue, so that a large part of the gland can be readily shelled out of its bed. This is especially the case over the lower part of the gland—an arrangment which must facilitate the movements of the jaw.

The **parotid duct**, named also **Stensen's duct**, appears at the anterior border of the gland, about one finger's breadth below the zygoma, and runs forwards over the masseter muscle, accompanied by the accessoria parotis, when that accessory portion of the gland exists, and receiving its ducts. At the anterior border of the masseter, the duct turns inwards through the fat of the cheek and pierces the buccinator muscle; and then, after running for a short distance obliquely

forwards beneath the mucous membrane, opens upon the inner surface of the cheek by a small orifice on a papilla opposite the crown of the second molar tooth of the upper jaw. Its direction across the face may be indicated by a line drawn from the lower margin of the concha of the ear to a point midway between the red margin of the lip and the ala of the nose. The length of the parotid duct is 5 cm. to 6 cm., and its diameter about 2 mm. to 3 mm. The lumen of the duct is about 1 mm. in diameter, except where it pierces the mucous membrane. Here it contracts, and will only admit a hog's bristle.

The mode of distribution of the parotid duct within the gland has been investigated by Joucour ('Considérations anatomiques sur le canal parotidien,' *Thèse de Bordeaux*, 1898), and Kermauner ('Zur Kenntnis des mikrosk. Baues der Parotis,' *Arch. klin. Chir.*, Bd. lix.). From these observations it appears that the main duct runs backwards for some distance in the gland before dividing into an upper and a lower branch. The lower branch is the larger of the two, and it turns downwards to the lower border of the gland.

Blood-vessels, lymphatics, and nerves.—Arteries.—The gland is supplied mainly by the transverse facial branch of the temporal artery, but it also gets a few small twigs from the external carotid and the internal maxillary arteries. The **veins** terminate in the temporal, internal maxillary, and temporo-maxillary veins as these traverse the gland. The **lymphatics** join the deep and superficial glands in the neck and there are often one or more lymphatic glands embedded in the substance of the parotid.

The **nerves** come from the sympathetic plexus on the external carotid artery, and also from the facial, the auriculo-temporal, and great auricular nerves. In the dog and cat, it has been experimentally shown that the parotid derives its cerebro-spinal nerve-supply from the glosso-pharyngeal, through the lesser superficial petrosal nerve and the otic ganglion, the fibres finally passing to the gland by a branch of the auriculo-temporal.

Varieties.—An instance is recorded by Gruber of a remarkable displacement of the parotid on one side; the whole gland being situated on the masseter muscle as if it were an enlarged accessory parotid (*Virchow's Archiv*, xxxii.). Its absence has also been recorded by Poirier (*Bulletins de la société anat. de Paris*, 1888), and by Becco (*Atti della Acad. Med. de Genova*, Anno xi., 1896).

Glandula submandibularis (gl. submaxillaris).—The submandibular gland, next in size to the parotid, is situated internal to and below the posterior part of the body of the mandible. Its greatest vertical extent is about 4 cm.; its antero-posterior, 3 cm.; and it measures 2 cm. to 2·5 cm. from the superficial surface inwards. It weighs about 8 grm. to 10 grm.

The gland has a somewhat flattened oval form with the long axis nearly vertical, and its surfaces may be described as external and internal (fig. 20). The external surface is convex, and its upper and smaller portion lies against the inner surface of the internal pterygoid muscle, and in front of this against the jaw just above its lower border. The lower and larger portion extends downwards into the neck, and is subcutaneous, being covered merely by the skin, superficial fascia, platysma, deep fascia, and the facial vein. This subcutaneous surface lies below the jaw, opposite the insertion of the masseter muscle, and has an area on an average of about 3 cm. by 2 cm. It reaches backwards to the sterno-mastoid, and above comes into relation with the parotid gland behind the angle of the jaw. The deep surface of the gland lies on the lateral surface of the posterior belly of the digastric and the stylo-hyoid muscles. It also extends above these muscles, where it lies on the stylo-glossus and hyo-glossus muscles and the hypoglossal nerve; while below them, it reaches into the carotid triangle and overlaps the great cornu of the hyoid bone, the hypoglossal nerve, and the lingual artery.

The external maxillary artery, before it mounts over the mandible, lies in a deep groove upon the back part and upper border of the gland, while the vein, as mentioned above, is placed on the superficial surface of the gland. From its upper and anterior part, two thin processes of the gland pass forwards, separated by a groove, lodging the free posterior border of the mylo-hyoid muscle. The lateral process extends a short distance on the mandibular surface of the mylo-hyoid muscle, and the median process passes forwards on the lingual surface of this muscle, having the submandibular duct and the lingual nerve above it, and ends at the posterior extremity of the sublingual gland.

The **duct of the submandibular gland,** or *Wharton's duct* (figs. 16 and 26), which is about 4 cm. to 5 cm. long, with a diameter of 2 mm. to 3 mm., is thin walled as compared with the parotid duct. It leaves the main portions of the gland above the internal process just described, and runs forwards between the mylo-hyoid and hyo-glossus muscles, and then along the floor of the mouth, having the genio-glossus and inferior lingualis internal to it and lying first upon, then to the inner side, and lastly again above the sublingual gland to reach the side of the frenulum linguæ. Here it terminates, close to the duct of the opposite side, by a narrow orifice, which opens at the summit of a soft papilla (fig. 5) seen beneath the tongue. Near its commencement, the lingual nerve passes downwards and forwards, external to it, and then inclines inwards below it, and at the anterior border of the hyo-glossus muscle it lies close to the hypoglossal nerve and lingual artery.

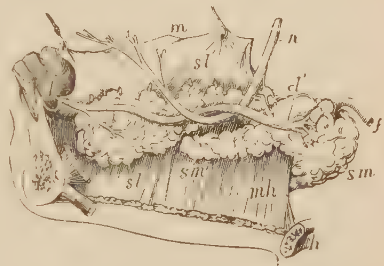


FIG. 26.—VIEW OF THE RIGHT SUBMANDIBULAR AND SUBLINGUAL GLANDS FROM THE MEDIAN ASPECT. (Allen Thomson.)

Part of the right side of the jaw, divided from the left at the symphysis, remains; the tongue and its muscles have been removed; and the mucous membrane of the right side has been dissected off and hooked upwards so as to expose the sublingual glands; *s m*, the larger superficial part of the submandibular gland; *f*, the external maxillary artery passing through it; *s m'*, deep portion prolonged on the inner side of the mylo-hyoid muscle, *m h*; *s l* is placed below the anterior large part of the sublingual gland, with the duct of Bartholin partly shown; *s l'*, placed above the hinder small end of the gland, indicates one or two of the ducts perforating the mucous membrane; *d*, the papilla, at which the submandibular duct opens in front behind the incisor teeth; *d'*, the commencement of the duct; *h*, the hyoid bone; *n*, the lingual nerve; close to it is the submaxillary ganglion.

The ducts radiate in various directions from the hilum, and J. M. Flint ('The Ducts of the Human Submaxillary Gland,' *Amer. Jour. of Anatomy*, vol. i.) gives the following as an approximate estimate of the branchings of the duct: 'The ductus submaxillaris divides into three primary ducts, which divide into eighteen interlobular ducts, which divide into ninety-six sublobular ducts, which divide into one thousand five hundred lobular ducts.' This gives one thousand five hundred lobules in the entire gland.

Blood-vessels, lymphatics, and nerves.—The **arteries** to the submandibular gland come from the external maxillary and sometimes also from its submental branch, while the blood is returned into the facial vein. The blood-vessels do not enter the gland along with the duct, but they soon join it, and then follow closely the duct in its distribution through the substance of the gland.

Lymphatics.—The submandibular gland resembles the parotid in having some lymph nodules embedded in its substance. The lymphatic vessels pass chiefly to the lymphatic glands lying along the lower border of the mandible.

Nerves.—The chorda tympani branch of the facial nerve, and the sympathetic fibres from the plexus on the external maxillary artery, reach the gland through the submaxillary ganglion.

Varieties.—Gruber (*Virchow's Archiv*, Bd. cii.) has recorded a case of complete absence of both submandibular glands. Turner (*Jour. Anat. and Phys.* vol. iv., 1870) described a case where both submandibular glands were smaller than normal and situated entirely on the upper or lingual aspect of the mylo-hyoid muscle.

Glandula sublingualis.—The sublingual gland (figs. 16, 17, 18, 19, and 26), the smallest of the salivary glands, is of a narrow oblong shape, and weighs scarcely 4 grm. It is situated in the floor of the mouth, where it forms a ridge between the tongue and the gums of the lower jaw, covered only by the mucous membrane. It extends from the frenulum linguæ in front, where it is in contact with the gland of the opposite side, obliquely backwards and outwards, for rather more than 4 cm.

In about the anterior two-thirds of its extent, it lies in close relation with the inner surface of the lower jaw above the mylo-hyoid ridge, and has the mylo-hyoid muscle below it; but posteriorly, this muscle separates it from the bone (see figs. 17, 18, and 19). The genio-hyoid and genio-glossus lie to its inner side. The lingual and hypoglossal nerves and Wharton's duct lie above it posteriorly, but they gradually pass to its inner side.

The lobules of the sublingual gland are not so closely united together as those of the other salivary glands, and the ducts from many of them open separately into the mouth, along the ridge which indicates the position of the gland. These ducts, named **ductus sublinguales minores** (*Ducts of Rivinus*), are from eight to twenty in number. Some of them are said to open into the duct of Wharton, but this is denied by Birmingham.

One, longer than the rest—**ductus sublingualis major** or duct of Bartholin (which is occasionally derived in part also from the submandibular gland)—runs forwards beside the Whartonian duct, and opens either with it or very near it, but it is inconstant in its occurrence (Chievitz, Suzanne).

Schulte ('The Development of the Human Salivary Glands,' in *Contributions to the Anatomy and Development of the Salivary Glands in the Mammalia*, Columbia University Press, 1913) describes the sublingual gland as the sublingual mass, which is made up of a number of distinct components: namely, the lesser sublingual (Rivinian) glands, the greater sublingual (Bartholinian) gland, and the supra-mylohyoid lobules of the submandibular gland. Of these, the lesser sublingual glands alone are constant.

Blood-vessels, lymphatics, and nerves.—The **blood-vessels** of this gland are supplied by the sublingual and submental arteries and veins. The **lymphatic** vessels join the lateral group from the tongue. The **nerves** are numerous, and are derived from the lingual branch of the fifth, the chorda tympani, and the sympathetic.

DENTES.

In the human subject, as in the great majority of mammals, the dentition is *diphyodont*—that is, two sets of teeth make their appearance in the course of life, of which the first comprises the *temporary* or *milk-teeth* (dentes decidui); while the second is the *permanent* set (dentes permanentes). The temporary teeth are twenty in number—ten in each jaw—and the permanent set consists of thirty-two—sixteen above and sixteen below.

The human dentition is also *heterodont*; the teeth, instead of all having the same form (*homodont* condition), differ considerably in their size, shape, and function. The twenty deciduate teeth consist of four incisors, two canines, and four multicuspids or molars, above and below. The thirty-two permanent teeth are four incisors, two canines, four premolars or bicuspids, and six molars, in each jaw. There are no premolars among the temporary teeth; the eight deciduous molars preceding eight premolars of the permanent set. The relative position and arrangement

of the different kinds of teeth may be expressed by the following formulæ, which also exhibit the relation between the two sets in these respects :—

		MO.	CA.	IN.	IN.	CA.	MO.			
Deciduate teeth	Upper	2	1	2	2	1	2	=	10	= 20
	Lower	2	1	2	2	1	2	=	10	

		MO.	PM.	CA.	IN.	IN.	CA.	PM.	MO.			
Permanent teeth	Upper	3	2	1	2	2	1	2	3	=	16	= 32
	Lower	3	2	1	2	2	1	2	3	=	16	

Or they may be written more simply thus :—

$$\text{Deciduate teeth} \left\{ \frac{2\ .\ 1\ .\ 2}{2\ .\ 1\ .\ 2} \right.$$

$$\text{Permanent teeth} \left\{ \frac{2\ .\ 1\ .\ 2\ .\ 3}{2\ .\ 1\ .\ 2\ .\ 3} \right.$$

The three permanent molars are by some regarded as deciduate teeth without calcified vertical successors.

The curve occupied by the teeth of the upper jaw is elliptical, and of the lower parabolic. It is not broken by any interval or diastema, as is the case in most mammals; indeed, the crowns of nearly all the teeth possess facets near the masticatory surface due to the contact of adjacent teeth, but towards the gums the crowns diverge somewhat from one another so as to leave small spaces between them (see fig. 29). The span of the upper dental arch (arcus dentalis superior) is rather larger than that of the lower one (arcus dentalis inferior), so that the teeth of the upper jaw slightly overlap those of the lower, both in front and at the sides. While there is a slight diminution in the height of the crowns of the teeth from the incisors backwards to the wisdom-teeth, there is in man no abrupt change of level along the range. In consequence of the large proportionate breadth of the upper median incisors, the other teeth of the upper jaw are thrown somewhat outwards, so that in closure of the jaws the canines and premolars come into contact partly with the corresponding lower teeth, and partly with those next following; and in the case of the molars, each cusp of the upper lies behind the corresponding cusp of the lower teeth. Since, however, the upper molars—and especially the wisdom-teeth—are smaller than those below, the dental arches terminate behind nearly at the same point in both jaws (see figs. 29 and 31).

FIG. 27.—LOWER ASPECT OF SUPERIOR DENTAL ARCH AND HARD PALATE. (Mühlreiter.)

In Europeans, the upper incisors project in front of the lower incisors; but it has been shown by Turner[1] that in some, at least, of the Australian aborigines this is not the case—the cutting-edges of the lower incisors projecting as far forwards as those of the upper.

[1] 'The Relations of the Dentary Arcades in the Crania of Australian Aborigines,' *Jour. Anat. and Phys.*, vol. xxv., July 1891.

It is well known that the teeth of certain races are larger in relation to the general stature of the individual than in others. Flowers[1] investigated this question—so far as the premolars and molars are concerned. He constructed a *dental index* by comparing the distance between the anterior surface of the first premolar and the posterior surface of the wisdom-tooth with the *basio-nasal* length of the skull, and divided the various races according to their dental index into *microdont, mesodont,* and *megadont.* The microdont section contains the white races, the mesodont the Mongolian or yellow races, and the megadont the black races, including the Australians.

Fig. 28.—Upper aspect of lower dental arch and body of lower jaw. (Mühlreiter.)

In consequence of the curve of the dental arch, such terms as anterior, posterior, internal, and external, when used in the description of the surfaces of the teeth, are liable to lead to confusion; to obviate which, special names must be employed. The surface of a tooth directed towards the lips or cheek is therefore called labial or buccal, and that towards the tongue the lingual or palatine; while the terms proximal and distal are used to represent the surfaces that would look towards and away from the median plane were the teeth arranged in a straight line passing outwards from the median incisor.[2]

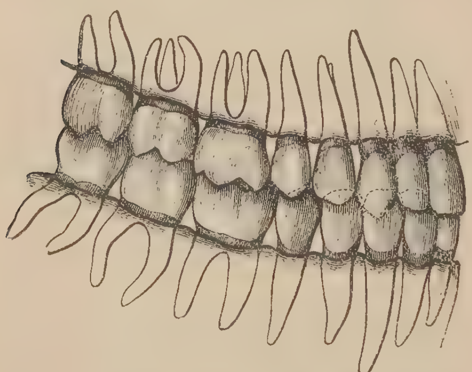


Fig. 29.—Labial aspect of the right half of the two dental arches to show the relation between the upper and lower teeth. (Zuckerkandl.)

GENERAL FORM AND STRUCTURE.

A **tooth** consists of three portions—namely: one which projects above the gums and is named the *body* or *crown*; another fixed in the alveolus or socket—the *root*—consisting of a *fang* or *fangs*; and a third, intermediate between the other two, and, from being more or less constricted, named the *neck*. The size and form of each

[1] 'On the Size of the Teeth as a Character of Race,' *Journal of the Anthropological Institute,* vol. xiv., November 1884.

[2] In the Basle *Nomina anatomica,* the superficial aspect of the incisors and canines is called labial, and that of the premolars and molars buccal, and the proximal and distal surfaces of the incisors and canines median and lateral; while for the corresponding surfaces of the premolars and molars the terms anterior and posterior are employed.

of these parts vary in the different kinds of teeth. The crowns of all the teeth present five surfaces—namely: masticatory, labial or buccal, lingual or palatine, proximal, and distal. In the incisors, the masticatory surface is represented by a cutting edge; in the canines it is more or less pointed; and in the premolars and molars quadrilateral.

Fig. 30.—Lingual aspect of the left half of the two dental arches. (Zuckerkandl.)

The roots of the teeth may be single, or divided into two or three fangs. They are accurately fitted to the alveoli of the jaws, in which they are implanted. Each alveolus is lined by periosteum (*alveolar periosteum*, fig. 32), which also invests the contained tooth as high as the neck, and is blended above with the dense tissue

Fig. 31.—A skiagram of the jaws and teeth of the right half of an adult male skull. (Symington and Rankin.)

The specimen was placed in relation to the X-rays so as to appear as if viewed from the right side and somewhat from the front. The floor of the maxillary antrum is indicated by a whitish line lying close to the apices of the fangs of the molars and ascending in front a short distance from the second premolar.

of the gums. The fangs of all the teeth taper from the neck to the point, and this form, together with their accurate adjustment to the alveolus, has the effect of distributing the pressure during use over the whole socket, and of preventing it from unduly bearing on the point of the fang, through which the blood-vessels and nerves enter.

The hard calcified portion of a tooth is composed mainly of a material termed dentine; this is covered on the crown by a layer of enamel, and in the roots by cementum or crusta petrosa. The dentine surrounds a space in the interior of the tooth known as the pulp cavity. This contains blood-vessels, nerves, and connective tissue, and is lined by cells termed odontoblasts. The histology and chemical composition of the various parts of a tooth are given in Part I. of this volume.

The pulp cavity (*cavum dentis*) varies in shape according to age and to the form of the crown and the number of fangs. It is larger in young growing teeth than

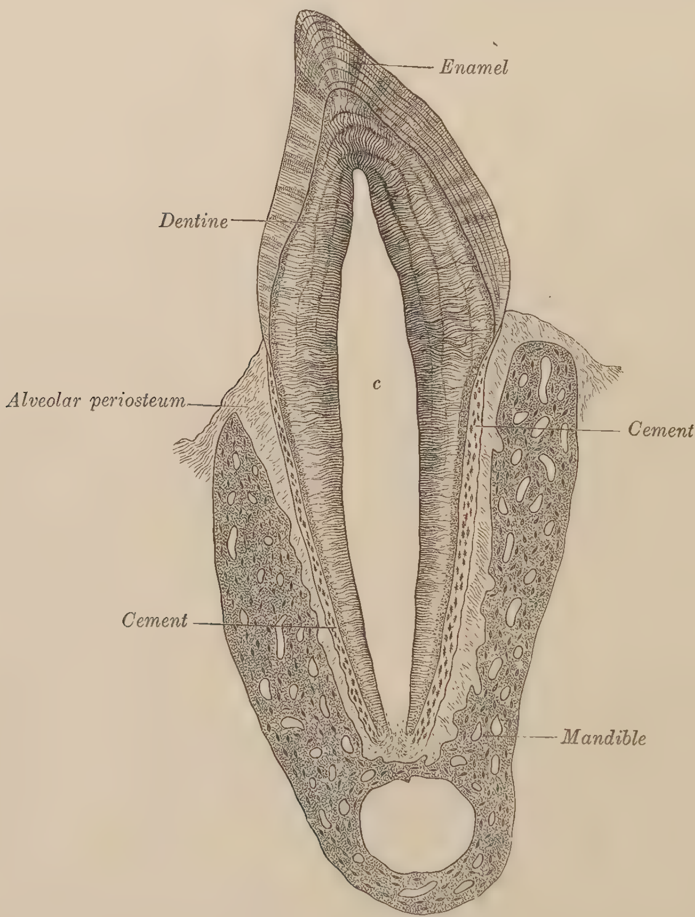


FIG. 32.—VERTICAL SECTION OF PREMOLAR OF CAT. (Waldeyer.)
The tooth is shown embedded in its alveolus. *c*, pulp cavity.

in fully developed ones. In teeth where the crown has more than one cusp, the pulp cavity has an extension corresponding to each cusp, and it also passes down the root, or each fang, to end at its apex in a small aperture through which the blood-vessels and nerves enter the pulp cavity.

SPECIAL CHARACTERS OF THE TEETH.

THE PERMANENT TEETH.—The **incisors** (fig. 35), eight in number, are the four front teeth in each jaw, and are so named from being adapted for cutting or dividing the food. Their *crowns* are chisel-shaped (*c*), and have a sharp horizontal cutting

edge, which by continued use is bevelled off behind in the upper teeth, but in the lower is worn down in front, where it comes into contact with the over-lapping edges of the upper teeth. Before being subjected to wear, the horizontal edge of each incisor is marked by three small prominent points, separated by two slight

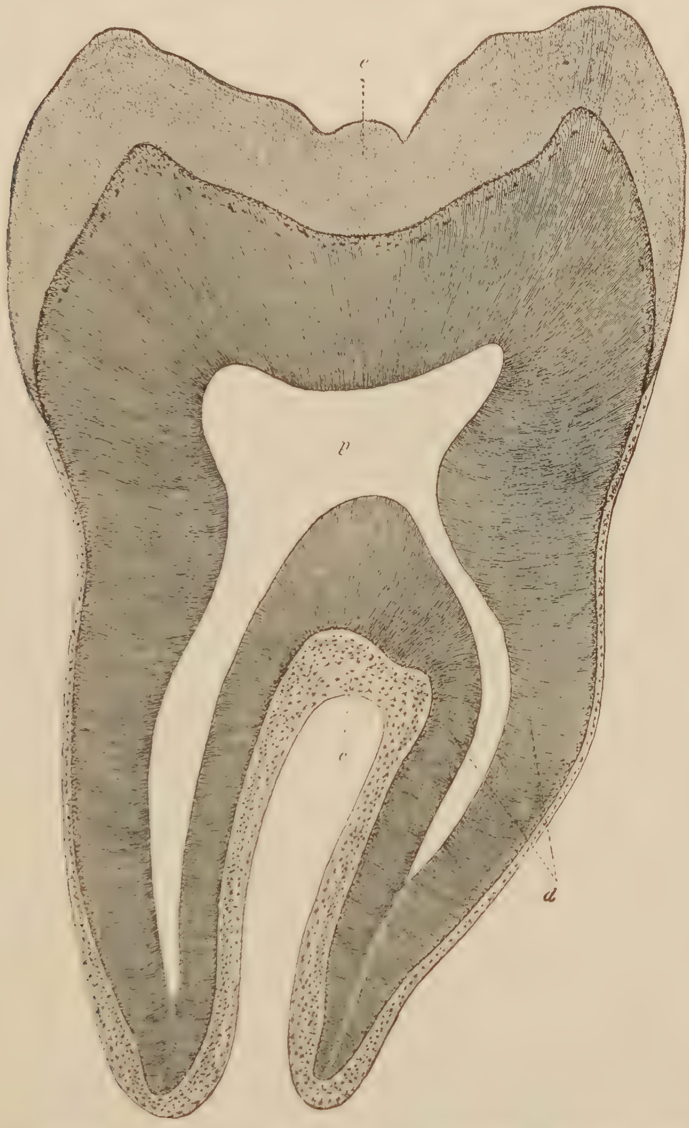


FIG. 33.—LONGITUDINAL SECTION OF A MOLAR TOOTH. Magnified eight diameters. (Sobotta.) *p*, pulp cavity; *d*, dentine; *c*, cement; *e*, enamel.

notches (fig. 35, *d*). The labial surface of the crown is slightly convex, both from above downwards, and from side to side. The lingual surface is concave, especially from above downwards. The median and lateral surfaces are triangular with the base at the gum, and the apex towards the cutting-edge. The enamel is prolonged towards the base of the crown on both the lingual and labial surfaces, so that its termination is indicated by a curved line with its convexity towards

the gum; while on the median and lateral surfaces the line is concave. The root is long, single, conical, and compressed at the sides, where it sometimes—though rarely—presents a slight longitudinal furrow (as in fig. 35, *c*). The lower incisor teeth are placed vertically in the jaw, but the corresponding upper teeth are directed obliquely forwards. The pulp cavity terminates towards the cutting-edge

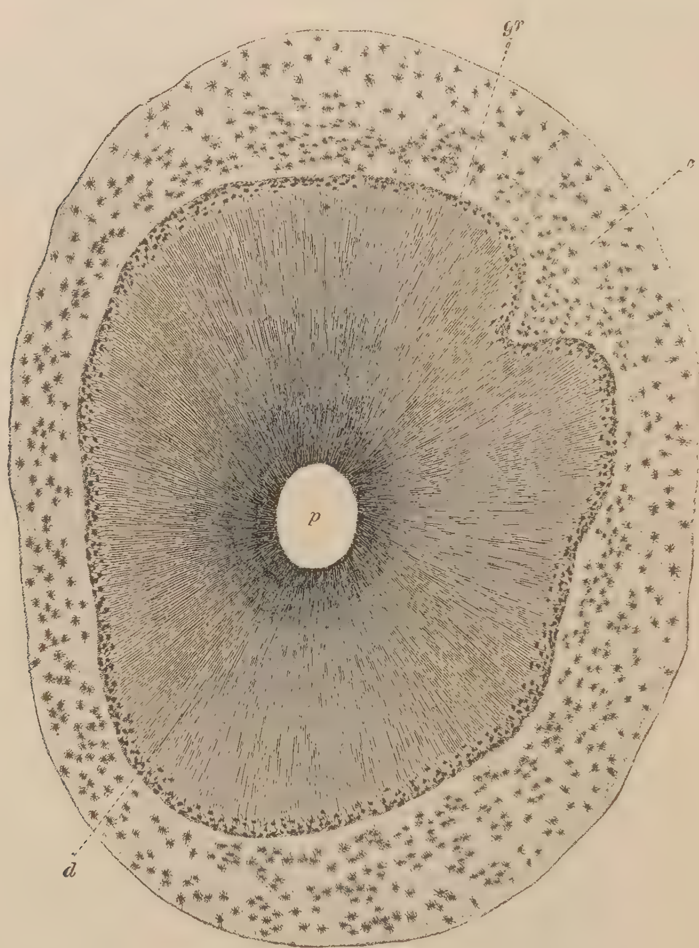


Fig. 34.—Section of a human canine tooth, across the root. Magnified twenty-five diameters. (Sobotta.) *p*, pulp cavity; *d*, dentine; *gr*, its granular layer; *c*, cement.

of the crown in slight proximal and distal cornua; in the neck and root it is cylindrical, but at the apex of the root it is constricted.

The upper median incisor is the largest of all the incisor teeth, and the median angle of its cutting-edge is rather more acute than the lateral angle. Its lingual surface generally possesses two slight ridges, which meet above, near the gum, to form a small tubercle, and enclose a triangular depression (see fig. 36, *c*). Sometimes the tubercle projects downwards to form a lingual cup (see fig. 36, *a*), and in other cases a faint vertical elevation divides the lingual depression into two (see fig. 36, *b*).

The upper lateral incisor is smaller in every direction than the median; the lower distal angle of the crown is more rounded, and the depression on the

lingual surface just below the tubercle is generally more marked than in the median incisor.

The lower median incisor is the smallest of all the incisors, and its cutting-edge is only about half the breadth of that of the corresponding upper tooth. The root is markedly compressed from side to side. The depression usually present on the lingual surface of the upper incisors is absent, but the tubercle may be fairly well marked.

Fig 35.—Incisor teeth of the upper and lower jaws.

a, front view of the upper and lower median incisors; *b*, front view of the upper and lower lateral incisors; *c*, lateral view of the upper and lower median incisors, showing the chisel shape of the crown; a groove is seen marking slightly the root of the lower tooth; *d*, the upper and lower median incisor teeth before they have been worn, showing the three points on the cutting-edge.

The lower lateral incisor is larger than the lower median, and its long, markedly compressed root often has a vertical groove on its median and lateral surfaces. The lateral angle is rounded off, though not so markedly as in the upper lateral incisor.

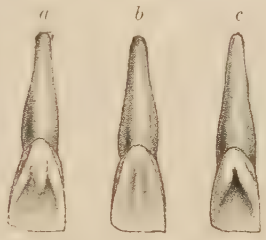


Fig. 36.—*a*, *b*, *c*, lingual surface of upper incisor teeth, showing variations in form; in *a* the cingulum is well marked. (Zuckerkandl.)

The **canine** teeth (fig. 37), four in number, are placed one on each side, above and below, next to the lateral incisors. They are larger and stronger than the incisor teeth, and are the longest of all the teeth. The *crown* is thick and conical, its labial surface decidedly convex, and the lingual less so. It may be compared to that of a large incisor tooth, the angles of which have been removed, so as to leave a single central point or *cusp*, whence the name *cuspidate* applied to these teeth. The point always becomes worn down by use. The distal side of the crown is convex and longer than the proximal, by which character the side to which a canine tooth belongs may be determined. The root of the canine teeth is single, conical, and compressed at the sides: it is longer than the root of any of the other teeth, and is so thick as to cause a prominence of the alveolar arch. The pulp cavity extends towards the apex of the crown as a single process, and it passes into the neck without any marked constriction.

Fig. 37. Canine tooth of the upper jaw.

a, front view, *b*, lateral view, showing the long fang grooved on the side.

The upper canines—popularly called the *eye-teeth*—are larger than the lower, and in consequence of this, as well as of the greater width of the upper range of incisors, they are thrown a little farther outwards than the lower ones. On their lingual surface, a well-marked ridge passes from the apex of the cusp to a distinct basal tubercle. The root is

compressed proximo-distally, and its flattened surfaces are grooved longitudinally, but only very rarely is it completely divided.

The lower canine has neither a lingual ridge nor a tubercle, and the enamel extends farther down on the labial than the lingual surface. The root is often more or less bifid, and sometimes it has two distinct fangs.

In the dog tribe, and in the carnivora generally, these teeth acquire a great size, and are fitted for seizing and killing prey, and for gnawing and tearing it when taken as food.

The **premolars** (fig. 38), also called *bicuspids*, are four in each jaw; they are shorter and smaller than the canines—next to which they are placed. The crown is compressed proximo-distally, and both its buccal and lingual surfaces are convex. The grinding-surface shows two cusps—a large buccal and a smaller lingual—separated by a deep fissure. The root is compressed in the same direction as the crown, and is grooved on its proximal and distal surfaces so as to show a tendency to be divided into a buccal and a lingual portion. The pulp cavity has two cornua in the crown—the size of these cornua varies according to the degree of prominence of the cusps; and in the root the cavity may exhibit traces of division even though the root is single. Where more than one fang is present, the pulp cavity sends a canal to the apex of each.

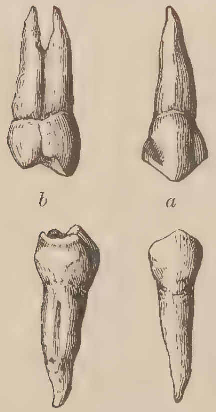


Fig. 38.—First premolar tooth of the upper and lower jaws.

a, labial view, *b*, lateral view, showing the lateral groove of the root and the tendency in the upper to division.

The upper premolars are larger than the lower, their lingual cusps are well developed, and the differences between the first and second are slight. The buccal surface of the crown of the first upper premolar has a vertical ridge passing from its apex upwards towards the neck; this ridge is bounded by two lateral depressions (see *a*, fig. 38). The lingual surface of the crown is smaller and more convex both longitudinally and transversely than the buccal aspect. The root may be single; more usually it is divided into two—a buccal and a lingual; and sometimes three—two buccal and one lingual. In the second upper premolar, the buccal and lingual surfaces are nearly equal, and the buccal ridge is indistinct, while the root is more frequently single than in the first premolar.

The lower premolars are smaller than the upper ones, their cusps are less deeply divided, and the lingual surface is much less convex than the buccal. In the upper premolars the two cusps are separated by a deep fissure, while in the lower they are united by a low ridge. The lower premolars have generally single roots, but occasionally the root is divided into a buccal and a lingual fang. The first lower premolar has sometimes only one cusp distinctly marked—namely, the buccal—and in that case it approaches in figure to a canine tooth. The second premolar is larger than the first, and its lingual cusp is nearly as prominent as the buccal one, whereas in the first premolar the lingual cusp is much smaller.

M. De Terra ('Beiträge zu einer Odontographie des Menschenrassen,' *Berlinische Verlagsanstalt*, 1905) has described a case where both the first and second upper premolars had three fangs.

The **molar** teeth (fig. 39), true or large molars, or *grinders*, are twelve in number, and are arranged behind the premolar teeth—three on each side, above and below. They are distinguished by the large size of the crown, and by the great width of its grinding-surface. In size and general form the molars differ from the premolars in a more marked degree than the other teeth from one another; indeed, the

adjacent incisors, canines, and premolars may by slight modifications be almost indistinguishable.

The first molar is the largest, and the third is the smallest in each row, producing a gradation of size in these teeth. The last of the row, owing to its late appearance through the gum, is called the *wisdom-tooth*. The *crowns* of the molar teeth are low and cuboid in their general form. Their buccal and lingual surfaces are convex, but the proximal and distal surfaces are flattened. The grinding-surface is nearly square in the lower teeth, and rhomboidal in the upper, the corners being rounded off; it bears four or five tubercles or cusps (whence the name *multicuspidate*), separated from each other by a crucial depression.

The crown of the first upper molar bears four cusps, situated at the angles of the masticating surface; of these, the proximo-lingual is the largest, and is usually connected with the bucco-distal cusp by a thick oblique ridge. This tooth has

FIG. 39.—FIRST MOLAR TOOTH OF THE UPPER AND LOWER JAWS.

They are viewed from the buccal aspect.

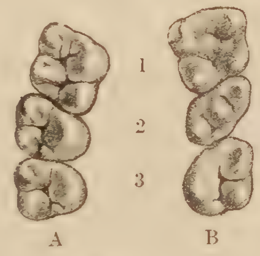


FIG. 40.—GRINDING-SURFACE OF THE UPPER MOLARS. (Zuckerkandl.)

A, on right side; the first molar has four cusps, and the second and third three each.

B, another set from the left side, with the same number of cusps as in A, except that a small additional cusp is seen on the lingual side of the proximo-lingual cusp of the first molar. The third molar is larger than the second.

FIG. 41.—GRINDING SURFACE OF THE LOWER MOLARS ON LEFT SIDE. (Zuckerkandl.)

In this series the first molar has five cusps, the second four, and the third four; and the teeth diminish in size from the first to the third.

occasionally a fifth cusp situated on the lingual side of the proximo-lingual cusp; this additional cusp is small, and rarely, if ever, reaches the grinding-surface. The second upper molar is generally described as having four cusps; but, according to Zuckerkandl [1] and Röse,[2] there are often only three. Zuckerkandl found four cusps in 45·6 per cent. of Europeans, the cusps being reduced to three in 54·4 per cent.; while in the lower races, four cusps were found in 73·5 per cent. Röse's results agree essentially with those of Zuckerkandl. In the upper wisdom-tooth the two lingual cusps are usually blended. The crowns of the lower molars, which are larger than those of the upper, have five cusps, the additional one being placed between the two distal ones, and rather to the buccal side. Not infrequently the second molar has only four cusps, but this reduction in the number of cusps rarely affects the first and third molars. The third molar is usually as large as and sometimes even larger than the second, and occasionally its cusps may be increased to six or seven. The *roots* of the molar teeth are multiple. In the first and second molars of the upper jaw, the fangs are three in number—namely, two buccal and one lingual; the buccal fangs are short, divergent, and directed towards the antrum of the maxilla, while the lingual fang is larger and longer and directed

[1] *Anatomie der Mundhohle*, 1891.
[2] 'Ueber die Entstehung und Formabänderungen der menschlichen Molaren,' *Anat. Anzeiger*, Bd. vii., 1892.

towards the palate, its distal border extending as far back as the bucco-distal fang. The first and second molars of the lower jaw have each two broad compressed fangs, one proximal and the other distal; they are grooved on the faces that are

FIG. 42.—MILK TEETH OF THE RIGHT SIDE OF THE UPPER AND LOWER JAWS.
a, the incisors; *b*, the canines; *c*, the molar teeth.

turned towards each other as if each consisted of two fangs fused together. In the wisdom-teeth of both jaws there is a marked tendency to the fusion of all the

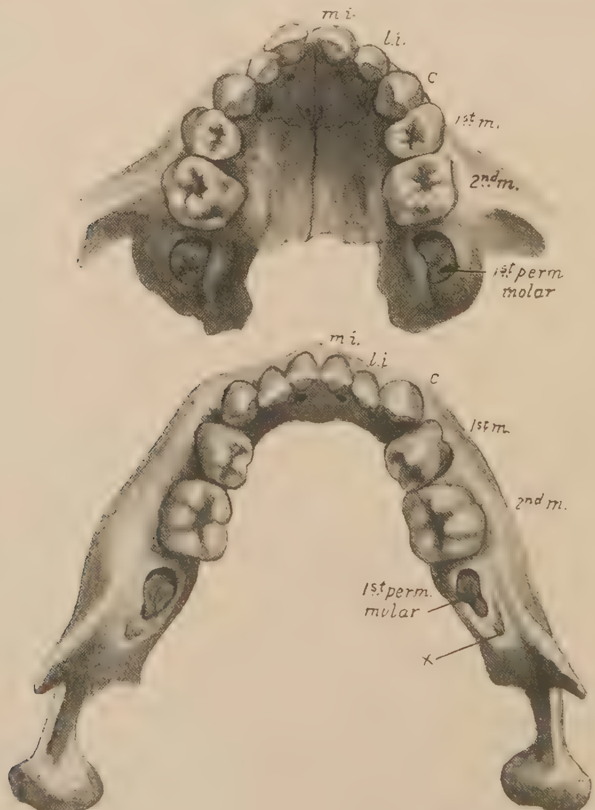


FIG. 43.—THE JAWS AND TEETH OF A CHILD AGED TWO YEARS, SHOWING THE DECIDUOUS TEETH ERUPTED, THE FIRST PERMANENT MOLARS IN THEIR BONY CRYPTS, AND × THE RECESS AT THE BASE OF THE CORONOID PROCESS FOR THE GERM OF THE SECOND PERMANENT MOLAR. Natural size. (J. Symington.)

fangs into a single irregular conical mass; Taylor[1] found this to occur in 90 per cent. of upper and 80 per cent. of lower wisdom teeth.

[1] 'Variations in the Human Teeth Form,' *Jour. Anat. and Phys.*, vol. xxxiii., January 1899.

The pulp cavity in the molar teeth is large at the neck; it ends in the crown in small diverticula corresponding in number to the cusps, and passes to the apex of each fang where it ends as the *foramen apices dentis.*

THE DECIDUOUS TEETH (fig. 42).—The deciduous, temporary, or milk-teeth are distinguished from the permanent by the marked bulging of the crown close to the neck, so that the latter shows a well-marked constriction. The deciduous incisors and canine teeth resemble those of the permanent set in their general form, but they are of smaller dimensions, and all their characteristic markings are much less decided — especially those in the canines.

The temporary molars are larger than the premolars which succeed them. The hinder of the two is much the larger, being, indeed, the largest of all the milk-teeth. The first upper milk-molar has only three cusps—two buccal and one lingual; the second has four. The first lower temporary molar has four cusps, and the second five, of which in the latter case three are buccal. The buccal surface of the lower molars slopes decidedly inwards as it passes upwards, so that the masticatory surface is reduced in size. The fangs of the deciduous molars resemble those of the permanent set, but they are smaller and are more divergent from the neck of the tooth, and the crowns of the temporary molars have their cusps more distinct.

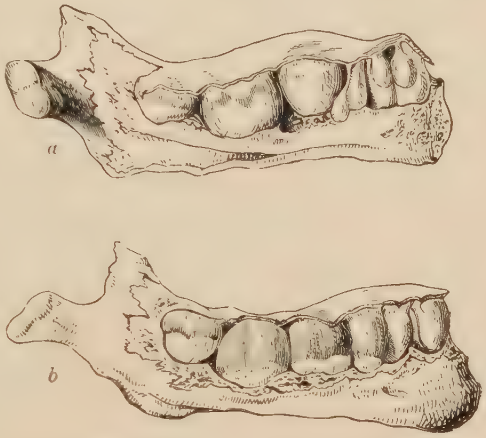


FIG. 44.—THE DENTAL SACS EXPOSED IN THE JAW OF A CHILD AT BIRTH. (Sharpey.)

a, the left half seen from the inner side; *b*, the right half shown from the outer side; part of the bone has been removed so as to expose the dental sacs as they lie below the gum; the lower figure shows the sacs of the milk teeth and the first permanent molar, exposed by removing the bone from the outside; the upper figure shows the same from the inside, together with the sacs of the permanent incisor and canine teeth adhering to the gum.

Teeth of prehistoric man.—The numerous remains of palæolithic man which have been discovered in recent years frequently include some teeth, the

FIG 45.—DIFFERENT STAGES IN THE FORMATION OF A MOLAR TOOTH WITH TWO FANGS. (Blake.)

1, the distinct caps of dentine for five cusps in the earliest stage of formation; in 2, and the remaining figures, the crown is downwards; in 2 and 3, the formation of the crown having proceeded as far as the neck, a bridge of dentine stretches across the base of the tooth-pulp; and in 4, the division of the fangs is thus completed; in 5, 6, and 7, the extension takes place in the fangs.

mandible, the calvaria, and the femur. The teeth which have been found up to the present exhibit distinctly human characteristics, and only differ in minor points from the teeth of existing races. In some cases, the lower incisors incline forwards so that their cutting-edge would meet directly and not be overlapped by the upper

incisors. The canines are on a level with the other teeth, and do not attain any unusual prominence. In some cases, the crowns of the lower molars increase in size from the first to the third—as in the gorilla. In the Gibraltar, Krapina, and Heidelberg specimens, the roots of the molars were very massive, and were united nearly up to the neck of the teeth (see A. Keith, 'Ancient Types of Man' (1911) which contains references to the original descriptions of the principal prehistoric human remains that have been discovered).

Blood-vessels, lymphatics, and nerves of the teeth.—All the teeth are supplied by branches of the internal maxillary **artery**. In the upper jaw, the posterior superior alveolar artery passes downwards on the tuberosity of the maxilla and gives off branches entering the posterior dental canals and furnishing twigs to the molar and premolar teeth. The infra-orbital artery gives off one or two anterior superior alveolar branches supplying the canine and incisor teeth. In the mandible, the inferior alveolar artery enters the mandibular canal, and, opposite the mental foramen, divides into two branches, one of which continues the direction of the main trunk and supplies the canine and incisor teeth, while the other reaches the surface of the mandible through the mental foramen. Each fang of a tooth receives a small branch, which enters the foramen at its apex, and, passing into the pulp cavity, breaks up into numerous twigs, which form a fine network just beneath the odontoblasts. The **veins** leave at the apices of the fangs, and pass through the bony canals with the arteries. They terminate in the pterygoid plexus. Attempts to inject directly the **lymphatic vessels** of the pulp cavity have failed, but G. Schweitzer ('Arch. f. mikr. Anat.,' Bd. lxiii.) succeeded in injecting them from the gums. The vessels from the teeth of both jaws end in the mandibular glands.

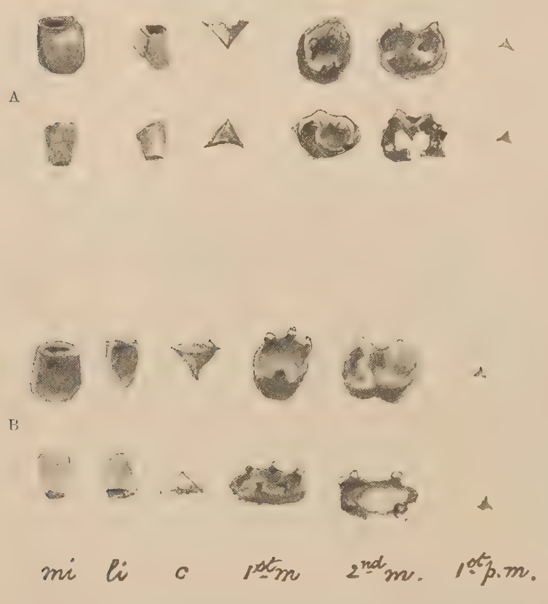


FIG. 46.—AMOUNT OF CALCIFICATION OF THE TEETH AT BIRTH. (J. Howard Mummery.)

A, viewed from without; B, viewed from within.

The teeth of the upper jaw are supplied by the maxillary, and those of the lower jaw by the mandibular division of the trifacial nerve. The branches of these nerves to the teeth follow closely the corresponding arteries, entering the pulp cavity by the apertures at the apices of the fangs, and, after forming a marginal plexus of neurofibrils beneath the dentinal tubules, traverse the dentine and end in arborisations beneath the enamel and cement (Mummery).

POST-NATAL DEVELOPMENT AND GROWTH OF THE TEETH.

The development of the teeth during intra-uterine life is described in Part I. of this volume. During this period, the germs of all the teeth—except the third permanent molars—appear, and at birth some of these teeth show a considerable

degree of development; but the premolars and second molars of the permanent set are in a very rudimentary condition, being represented merely by their enamel germs. The dental papilla of the second permanent molar appears about the fourth month after birth, that of the first premolar about the tenth month, and the second premolar about the eighteenth month; while the enamel germ and dental papilla of the third molar are not formed until the third year.

At birth, the teeth which are sufficiently developed to be visible to the naked eye, are the twenty deciduous teeth and the incisors, canines and first molars of the permanent set; none of these teeth are visible from the mouth, as they are covered by a thick, firm, mucous membrane forming the alveolar ridges. These teeth are

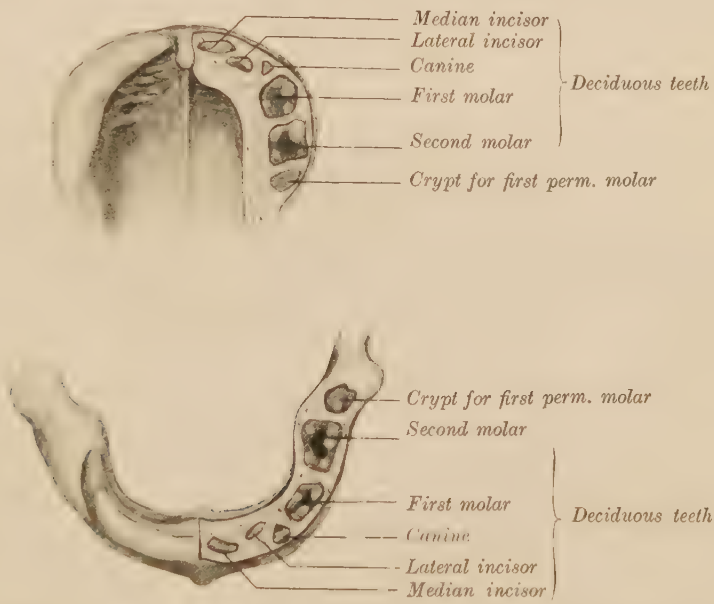


FIG. 47.—UPPER AND LOWER JAWS OF NEWLY BORN CHILD. Natural size. (J. Symington.)

On the right side, the gums are preserved; but on the left side they were sliced away until the milk teeth and the crypts for the first permanent molars were exposed.

enclosed in the dental sacs, which blend with the mucous membrane towards the surface and unite below with the periosteum lining the alveolar depressions in the jaws. These sacs can be exposed, as in figs. 44, *a* and *b*, and 49, by the removal of the median and lateral walls of the alveoli. This is most readily done in the mandible. The sacs seen from both aspects in this dissection are those investing the milk-teeth, the first permanent molars, and, on the median aspect in addition to these teeth, the permanent incisors and canine. The sacs cover the dental papillæ and enamel organs, and are best marked during the earlier stages of the calcification of the teeth.

The growth of the teeth advances steadily after birth, but so slowly that several years elapse between the commencement of calcification of a tooth and its complete development. In all the teeth, the process is essentially the same, but modified where the tooth possesses more than one cusp or root. The dental papilla, with the inner layer of the enamel organ which covers it, acquire the form and size of the crown of the future tooth. The formation of dentine commences on the surface of the papilla, from one or more centres, according to the number of cusps. Where the crown is bicuspidate, or multicuspidate, the separate centres become united

by an extension of the calcareous deposit over the masticatory surface. Calcification proceeds from the circumference of the papilla towards the future neck, until a cap of dentine covered by enamel is formed, which resembles in size and shape the crown of the future tooth, and this cap is gradually thickened by fresh deposits of

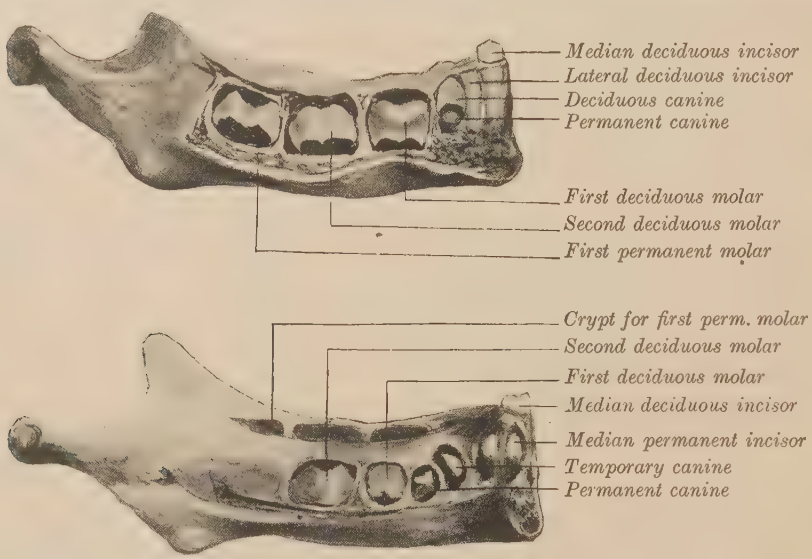


Fig. 48.—Mandible of child aged eight months, with teeth exposed on right half from the lateral aspect and on the left from the median aspect. Natural size. (J. Howard Mummery.)

dentine on its inner surface. In those teeth that have more than one root, septa grow inwards at the neck of the tooth and unite to subdivide its cavity into compartments corresponding in number to the roots or fangs to be formed. Each root is calcified from the neck towards the future apex, and until the growth of the tooth

Fig. 49.—Part of the lower jaw of a child aged three or four years, showing the relations of the deciduous and permanent teeth. (Sharpey.)

The specimen contains all the milk-teeth of the right side, together with the incisors of the left; the inner plate of the jaw has been removed, so as to expose the sacs of all the permanent teeth of the right side, except the eighth or wisdom-tooth, which is not yet formed. The large sac near the ramus of the jaw is that of the first permanent molar, and above and behind it is the commencing rudiment of the second molar.

is nearly completed the free end of the root terminates in a thin edge surrounding a large opening into the pulp cavity. The wall of the pulp cavity is thickened by successive deposits of dentine on its inner surface, and the apex of the root ultimately becomes solid with the exception of a minute central canal by which blood-vessels

and nerves reach the pulp cavity. This cavity is larger in the deciduous than in the permanent teeth, and in the latter a thick wall and a small pulp cavity are indications of a well-developed tooth. The enamel organ, and the enamel formed from its inner layer, invest only the crown of the tooth, and the dentine of the root becomes covered by cementum (substantia ossea).

At birth, calcification has commenced in all the milk-teeth, but only a thin shell is formed on the dental papilla. This process is more advanced in the incisors than in the other teeth, and has extended from their cutting-edges nearly as far as the future neck of the tooth. The canines have the apical portion of their crowns calcified. In the first molars, the masticatory surface is nearly completed, as the calcified cusps have become united with one another by an extension of the calcification over the areas between them ; but in the second molars, a considerable

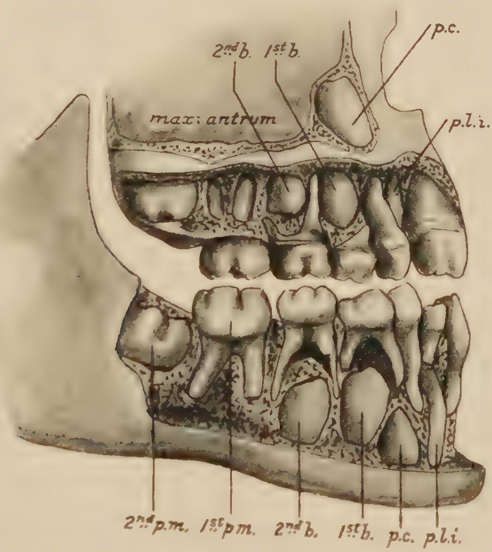


Fig. 50.—The teeth on the right side in a boy aged seven years, exposed from the lateral aspect. Natural size. (J. Symington.)

The erupted teeth of the upper jaw are the median permanent incisor, the temporary canine, the first and second temporary molars, and the first permanent molar. The lateral deciduous incisor is shed and has not yet been replaced by its permanent successor. The erupted teeth of the lower jaw correspond to those of the upper, except that the lateral deciduous incisor is still in position.

part of the masticatory surface is uncalcified, and one or more of the cusps may still be isolated. The antero-lateral cusp of the first lower molar has just commenced to calcify.

At the end of the first year after birth, the crowns of nearly all the milk-teeth possess a complete cap of dentine, and the roots of the incisors and first molars are beginning to appear. In a child two years old, the growth in length of the roots of the incisors and first molars is nearly complete, but their walls are still thin ; the canines have a large aperture at the apex, and the roots of the second molar are about half their full length. Although by this time all the milk-teeth are usually erupted, their roots are still growing. About the end of the third year, the incisors and first molars are fully formed, but the roots of the canines and second molars are still incompletely developed ; indeed, they probably continue to grow until the sixth year.

The permanent incisors begin to calcify about the sixth month after birth; their crowns are distinctly visible in skiagrams of the jaws of infants about a year old, and by the end of the third year are fully formed. The root grows slowly until shortly before its eruption and even after it has completely erupted, the root is still shorter than the crown. At about the tenth year, it has attained almost its full length, but the aperture at its apex is much larger than in an adult. The lateral incisor is somewhat later in its calcification than the median.

The crowns of the canines are only slightly later in their development than those of the incisors, but their root-formation is distinctly slower.

The first premolars begin to calcify at the third year, and the second at the fourth, and the crowns are completed about the seventh year; at the tenth year

Fig. 51.—Skiagram of the teeth and jaws of the right side from an infant aged one month. (Symington and Rankin.)

The lower deciduous teeth are seen and also the upper, but less distinctly. There is is a large crypt for the first permanent molar.

the root has acquired about half its normal length, and at the thirteenth its cavity is still conical with the base at the apex of the fang. The root is probably completely developed about the fifteenth or sixteenth year.

As already mentioned, the only permanent teeth which commence to calcify before birth are the lower first molars, and this process begins in the upper molars during the first month after birth. All the cusps of the first molars are calcified by the sixth month, and at the end of the first year the masticatory surface of their crowns is complete. The crown is completed in the third or fourth year; root-formation begins in the fifth year, and probably proceeds somewhat rapidly before the eruption of the tooth in the sixth year, when it has acquired rather more than

half its normal length. The growth of the root is probably not completed until about the tenth year. As this tooth begins to calcify just before birth, it takes about ten years to attain its full development.

The second molars begin to calcify in the fourth year, and the crown is not fully formed until about the eighth year; the roots grow slowly until shortly before the period for the eruption of the tooth. At thirteen, a comparatively large aperture at the end of the fangs indicates their incomplete development.

In the third molars, calcification starts about the tenth year, and I have found these teeth still destitute of fangs in subjects thirteen and sixteen years old.

The degree of calcification of the teeth at different periods of life is shown in fig. 31 and figs. 46 to 53.

Relations of the developing teeth.—During their development and growth, the relations of the teeth to one another and to the jaws undergo various

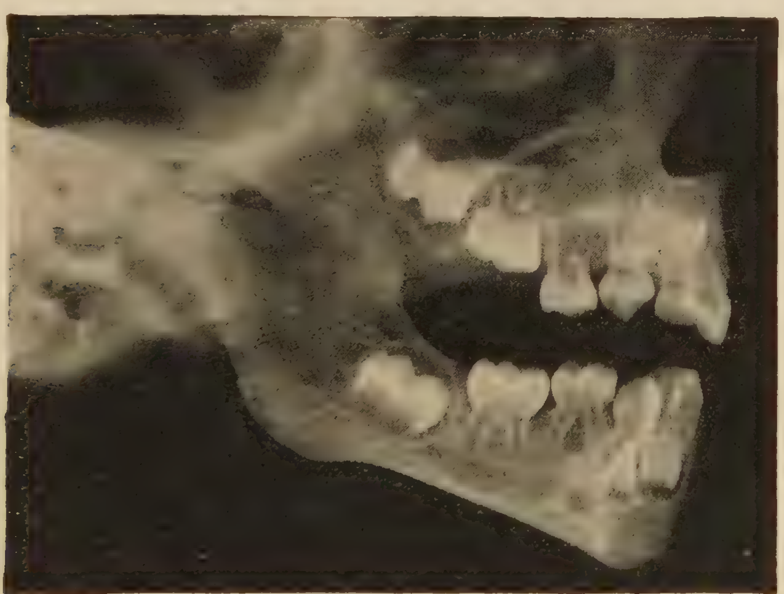


FIG. 52.—SKIAGRAM OF THE RIGHT HALF OF THE JAWS, ETC., OF AN INFANT AGED TWO YEARS. (Symington and Rankin.)

All the deciduous teeth are erupted except the second upper molar. The first permanent molars are still without roots.

important changes. The teeth are formed primarily quite independently of the jaws, and the intimate relation which subsequently exists between the teeth and their bony alveoli is only gradually acquired.

At birth, the milk-teeth, largely composed of non-calcified material, are situated in the alveolar processes of the jaws and do not project beyond the level of the alveoli. The septa between the sockets for the individual teeth are imperfectly developed; distinct apertures in the septa permitting of a communication between adjacent alveoli. The septum between the second temporary molar and the first permanent molar is only faintly indicated, and there is no bony wall behind the upper first permanent molar. The lower first permanent molar is situated in the base of the coronoid process.

During the period of six months after birth, when no temporary teeth usually erupt, the jaws are the seat of active growth. At about the sixth month, the greater part of the lower first permanent molar lies in the alveolar process and in front of

the base of the coronoid process. In both upper and lower jaws, the outer wall of the alveoli of the temporary molars has grown inwards at its free edge, so that the opening into the alveoli is smaller than the cavity, and these teeth cannot erupt without the previous absorption of this overhanging wall. By this alveolar growth, the temporary molars are protected from excessive pressure before their eruption. In the maxillæ, the antrum has extended outwards over the inner part of the temporary molars and of the first permanent molars, the alveoli for these teeth being separated from the antrum merely by a thin plate of bone, while a small cavity is formed a little in front of the antrum for the permanent canine.

FIG. 53.—SKIAGRAM OF THE RIGHT HALF OF THE TEETH AND JAWS OF A BOY AGED SIX YEARS. (Symington and Rankin.)

All the teeth, both deciduous and permanent, except the third molars, are present in this specimen.

During the eruption of the temporary teeth—*i.e.* from about the sixth to the twenty-fourth month—the alveolar process of the maxilla grows downwards and forwards, and the teeth descend as they erupt. These changes are not compensated for by a corresponding descent of the floor of the nose, nor by an expansion of the antrum and the growth of the roots of the teeth, so that the incisors gradually recede from the floor of the nose, and the canine and premolars from the antrum.

The twenty permanent teeth do not all lie in the maxilla above, nor in the mandible below the corresponding temporary teeth which they replace. The permanent incisors develop in alveoli situated on the lingual side of the temporary incisors, and the maxilla and mandible present apertures in this position leading into these alveoli (see fig. 43) ; but in consequence of the great breadth of the crown of the upper median incisors there is not room in the dental arch for the lateral

incisors, and these teeth become overlapped on the labial aspect by the median incisors. The alveolus for the median incisor reaches close to the floor of the nose, while the lateral incisor is near the palatine aspect of the alveolar process. The permanent canines, soon after their appearance, tend to migrate from the lingual side of the temporary canines—upwards in the maxilla and downwards in the mandible. As the alveolus of the permanent canine extends, it comes into close relation with the anterior wall of the antrum and the lateral wall of the nose, and its lower part lies on the labial side of the adjacent alveoli of the lateral incisor and of the first premolar. When these two teeth erupt, they diverge from one another, and thus leave a space between them for the canine. This divergence may not be sufficient, and the canine, after eruption, may project forwards beyond the line of the neighbouring teeth, giving rise to the condition known as buck-tooth.

As soon as the premolars are visible to the naked eye, they are found occupying crypts between the fangs of the corresponding temporary molars. In the upper jaws, these crypts lie a little below the anterior part of the floor of the antrum, and in the mandible reach below the level of the mental foramen.

We have already seen that at birth the arch of the lower milk teeth extends backwards nearly to the base of the coronoid process, and that the crypt for the first permanent molar is mainly situated in the base of this process. The changes in the mandible, by which space is gradually formed in the alveolar margin for the permanent molars, were described by John Tomes[1] and Humphrey.[2]

The breadth of the part of the arch of the mandible corresponding to the milk teeth and their successors, does not increase to any appreciable extent after birth, as measured from the median aspect, although the jaw becomes thickened by deposits of bone on its lateral aspect, and increased in vertical extent at the alveolar edge and the lower border. There is very little growth at the symphysis menti, after birth, and the two halves become united by bone about the middle of the first year. Space, therefore, for the permanent molars can only be obtained by a growth of the posterior part of the mandible, and this must be associated with an absorption and modelling of the new anterior border of the ascending ramus. During the first six years after birth, the anterior part of the ascending ramus is gradually absorbed, and the crypt for the first permanent molar in the fifth or sixth year lies in the alveolar margin. At this period, the second permanent molar is found in the base of the coronoid process, and by the twelfth or thirteenth year this tooth has gained the alveolar margin. A similar seat of origin, and subsequent advance into the alveolar margin, occurs in connection with the third molar, the process occupying from about the tenth to the twentieth year.

The upper permanent molars are formed at corresponding periods at the back of the maxillary tuberosity, from which they descend into the alveolar margin in regular sequence from the first to the third. When the upper jaw and the teeth are fully formed, the molars are the only teeth usually found just directly below the antrum, although sometimes the antrum extends forwards above the second premolar.

Eruption of the teeth.—Until a tooth is so far advanced in its development that the crown and part of the root are calcified, it remains embedded in the tissues beneath the gum. The process of eruption consists of the passage of the crown through the gum, and a completely erupted tooth presents the following characteristics: 'The crown of the tooth projects so that all the enamel is exposed, except that portion covered by the free margin of the muco-periosteum (gum). The

[1] *A System of Dental Surgery*, 1st edition, 1859.
[2] *British Journal of Dental Science*, vol. vi., 1862.

root of the tooth is firmly planted in the alveolus, which should be on a level with the neck of the tooth. The periodontal membrane is completely developed. The gum is firmly bound down to the bone, presenting a thin even margin in close contact with the tooth immediately beyond its continuation with the periodontal membrane.'[1]

The development of the teeth is associated with various changes in the surrounding parts, which must be considered in connection with the process of eruption. The inner layer of the enamel organ becomes converted into the enamel, the middle layer undergoes atrophy, and the outer layer is pushed outwards and forms a very delicate covering (dental cuticle, or Nasmyth's membrane) for the crown of the newly erupted tooth. The dental sac becomes thinned, and blends with the periosteum lining the alveolus. In almost all the teeth, the opening into the bony crypt is smaller than the crown of the tooth, and hence absorption of the margins of the opening must occur before the tooth can reach the gum. The eruption of the successors of the temporary teeth is preceded by an absorption of the roots of the latter and a shedding of the remains of these teeth.

Period of eruption of the deciduous teeth.—The eruption of these teeth does not occur in regular succession from behind forwards, as the first molars appear before the canines ; nor by a gradual and continuous process, but in batches, with intervals of repose between the successive periods of activity. The first to appear are the lower median incisors, then the upper median incisors, followed after a short interval by the upper lateral incisors, and after a longer interval by the lower lateral incisors. A. T. Spanton[2] examined 200 infants—100 males and 100 females—and out of these the lower median incisors appeared before the upper in 85·5 per cent. The average date of eruption in the males was 252 days, and in the female 221 ; this earlier eruption in females does not apparently apply to the other milk-teeth.[3] The first molars erupt at about the same time as the lower lateral incisors ; then after an interval of four or five months the canines, and finally, about the end of the second year, the second molars.

TABLE OF ERUPTION OF THE DECIDUATE TEETH.

Lower median incisors	6 to 9 months.
Upper incisors	8 to 10 months.
Lower lateral incisors and first molars	15 to 21 months.
Canines	16 to 20 months.
Second molars	20 to 24 months.

Cases of eruption of teeth before birth are rare, but Louis XIV. of France, Richard III. of England, Mazarin, Mirabeau, and others are cited as examples of its occurrence. The eruption before birth is usually limited to the lower median incisors, and such teeth may be quite normal and may persist until the usual period for their replacement by permanent incisors. Herpin ('Cas particuliers de dents à la naissance,' *Comptes Rendus des Anatomistes*, 1911) described a few cases in which minute rudimentary lower median incisors appeared through the gum a few days after birth. These teeth were mobile, and generally soon became detached. Non-appearance of the teeth is extremely uncommon. Giraldès (*Compte Rendu Soc. Biol.*, 1860–1) has recorded a case of absence of teeth in an infant sixteen months old.

Period of eruption of the permanent teeth.—The dates of eruption of the permanent teeth are more variable than those of the deciduous, since the twenty anterior teeth, which are the vertical successors of the deciduous set, are liable to have their eruption delayed when the deciduous teeth fail to be shed at the usual period,

[1] W. W. James and A. T. Pitts, 'Some Notes on the Dates of Eruption in 4,850 Children Aged under Twelve,' *Proc. Royal Soc. of Medicine*, vol. v., no. 5, 1912.
[2] 'The Normal Eruption of the First Milk Tooth,' *Brit. Med. Jour.*, January 8, 1907.
[3] J. Chérot, 'Étude statistique sur l'eruption des dents et leur age d'apparition,' *Thèse de Paris*, 1898.

and the eruption of the permanent molars is dependent upon a complicated series of changes in the jaws, by which space is found in the alveolar arch for them.

The average time of eruption of the lower teeth is shown in the following table :—

Molars, first	about the end of the	6th year.
Incisors, median	,, ,, ,,	7th ,,
,, lateral	,, ,, ,,	8th ,,
Premolars, first	between the	10th and 11th ,,
,, second	,, ,,	11th and 12th ,,
Canines	,, ,,	11th and 12th ,,
Molars, second	,, ,,	12th and 13th ,,
,, third (or wisdom)	,, ,,	17th and 25th ,,

As a rule, the upper teeth are six to twelve months later than the lower, but the first premolars are an exception, as the upper ones usually appear before the lower.

James and Pitts[1] have published the results of an examination of 4,850 children under twelve years of age, tabulating the cases together in periods of three months, ranging from five to twelve years, with a separate list of permanent teeth erupting prior to five years. These results are incomplete, owing to the age-limit of twelve years; but they are the most extensive observations on the period of eruption of the permanent teeth that have hitherto been recorded. These authors met with sixteen cases of the eruption of some—in only one case all—of the first molars prior to the age of five years, and by the end of the twelfth year all the first molars and the permanent incisors had erupted, while the remaining teeth had the following proportion of erupted teeth: lower first premolars, 77·5 per cent. and upper 86·8 per cent.; lower second premolars, 61·1 per cent. and upper 74 per cent.; lower canines, 74 per cent. and upper 57·4 per cent.; lower second molars 57·4 per cent. and upper 44·4 per cent.

Variations in the number of teeth.—The teeth of the temporary set seldom vary in number, but occasionally a lateral incisor may be absent, one or more supernumerary incisors be present, or two adjacent teeth found fused together (see Tomes, *Dental Surgery*, 2nd edition, 1873, p. 94, and C. Earle, 'On the Presence of a Supernumerary Milk-incisor in the Human Dentition,' *Jour. Anat. and Phys.* vol. xxix., 1905). Even in the permanent set, variations are not common; thus, amongst 19,725 schoolchildren, examined in Schleswig Holstein,[2] only thirty-three cases of supernumerary teeth were observed. In some instances it may be impossible to decide whether a supernumerary tooth belongs to the temporary or the permanent set. There has been a considerable amount of controversy as to the significance of numerical variations in children, more particularly with reference to the question of their atavistic nature. As the typical permanent mammalian dentition is I_3, C_1, PM_4, and M_3 on each side of each jaw, it follows that in man three pairs are suppressed: namely—one pair of incisors and two pairs of premolars. Where a supernumerary tooth is an incisor or a premolar, it may fairly be assumed to be a reversion to an ancestor provided with more teeth than man. As not more than two incisors are normally present in any of the primates, while a number of the lower primates have three molars, one would expect, on the theory that supernumerary incisors and premolars are atavistic, additional premolars to occur more frequently than additional incisors. This has not been proved to be the case; indeed, Dependorf found cases of supernumerary incisors more frequent than supernumerary premolars. In a typical dentition, the incisors may be distinguished as i_1, i_2, i_3, and the premolars as pm_1, pm_2, pm_3, and pm_4. Some consider that in man, i_2 is absent, and others i_3; while amongst the premolars, the missing teeth are probably pm_1 and pm_2 or possibly pm_1 and pm_4. Numerous cases have been recorded of fourth molars. Zuckerkandl[3] has shown that in persons from fourteen to nineteen years of age the dental lamina extends behind the third

[1] 'Some Notes on the Dates of Eruption in 4,850 Children, Aged under Twelve,' *Proc. Royal Soc. of Medicine*, vol. v., no. 5, March 1912.

[2] Dependorf, 'Zur Frage der überzähligen Zähne im menschlichen Gebiss,' *Zeitschrift f. Morphologie und Anthropologie*, Bd. x., 1907.

[3] 'Ueber das epitheliale Rudiment eines vierten Mahlzahnes beim Menschen,' *Sitzungsber. d. kais. Akad. d. Wissensch. Wien.*, Bd. 100, Abt. 3.

molar and is lodged in a small recess or groove in the jaw. This is really a repetition of what occurs in the early stages in the development of the other molars (see fig. 43). The fourth molar rudiment normally disappears, but in place of this it may develop into a distinct tooth. This is an excess in a serial repetition, and has no phylogenetic significance, as mammals possessing four molars are too remote from man.

At a meeting of the International Dental Federation, in August 1913, Prof. L. Bolk, of Amsterdam, exhibited about thirty specimens of additional permanent molars. Some of these were situated on the buccal aspect of and between the second and third maxillary molars: these he termed paramolars, while those found behind the third molars he named disto-molars. These additional teeth had molariform crowns, but only a single root (see *British Dental Journal*, vol. xxxv., no. 3, February 2, 1914).

Number of dentitions.—Although it is generally assumed that man, in common with the majority of mammals, is diphyodont, he would appear to be potentially polyphyodont. The mammalia are usually considered to be descended from the polyphyodont reptilian, and, if such be the case, we may expect to find that mammalian evolution has been associated with a reduction in the number of dentitions and that the monophyodont condition, instead of being as formerly supposed, the primitive one, represents a retrogressive step. In man, the diminution has proceeded so far that only two sets are fully developed and functional, but there is strong evidence in favour of the existence of traces of a prelacteal and a postpermanent dentition. Leche [1] has described rudimentary teeth in various pouch marsupials, situated on the labial side of the anterior milk-teeth, which he regards as prelacteal. P. Adloff [2] discovered a minute tooth in a ten-weeks' human embryo, situated on the buccal side of the second deciduate molar, which he termed prelacteal, and some of the dental rudiments occasionally found in the outer part of the alveolar margin of adult jaws are probably of this nature. The evidence in support of a postpermanent, often called tertiary, dentition rests mainly upon the reports of cases in which fresh teeth are stated to have appeared after the loss of some of the permanent set. A list of such cases has been compiled by Launois and Branea.[3]

Evolution of the molars.—The primitive tooth is a simple cone, forming what is known as the haplodont type, but in nearly all mammals the cheek-teeth are complex. Two main views are held as to the phylogeny of the multicuspidate teeth—such as the molars in man. According to one hypothesis, known as the concresence theory, these teeth are formed by the fusion of a number of originally simple cones, each cusp of a mammalian molar representing the apex of one of these cones. The evidence in favour of this view is mainly embryological, and is based partly upon the mode of development of the molars, in each of which the primary papillæ is not a simple papilla, but consists of several processes to which others may be added. The processes are separately calcified, and the crown is formed by the subsequent fusion of their bases. The concresence theory is supported by Röse,[4] and in a modified form by Kukenthal [5] and Marett Tims.[6] Cope,[7] Osborn,[8] and other American palæontologists, support what is known as the tritubercular theory. According to this view, the primitive mammalian molar tooth is triconodont, and is formed from a primitive conical tooth—the protocone—to which is first added a small anterior cone—the paracone—and then a small posterior one—the metacone. The tooth thus formed, possesses three cusps situated in an antero-posterior line; but these subsequently shift their position to form a triangle. In the upper jaw, the protocone moves to the palatine side, while the paracone and the metacone become respectively the anterior and posterior buccal cusps. In the lower jaw, the process is reversed; the protocone acquiring a buccal position and the paracone and the metacone become lingual, so that the base of the triangular upper molar is turned outwards and that of the lower molar inwards. Such teeth, while admirably adapted for cutting, are not suited for crushing, which is the principal function of the primate molars. The triangular cutting-molars have been transformed into quadritubercular crushing-teeth by the development of a talon or heel. The upper molars have developed a talon or heel which supports a posterior palatine cusp or hypocone. In this way, the four cusps of the upper molars have been developed. The evolution of the lower molar is much more complicated. It has lost its anterior lingual cone or paraconid, but its talon supports three tubercles—the posterior lingual (entoconoid), the posterior buccal (hypoconid), and the posterior median or hypoconoid.

[1] 'Zur Entwickelungsgeschichte des Zahnsystems der Saügetiere,' *Bibl. Zool.*, H. 17.
[2] 'Ueberreste einer praelactealen Zahnreihe beim Menschen,' *Deut. Monats. Zahnheilk.*, Jahrg. 27.
[3] 'Étude sur la troisième dentition chez l'homme,' *Jour. de l'Anat. et de la Phys.*, Année 32.
[4] 'Ueber die Entstehung und Formabänderungen der menschlichen Molaren,' *Anat. Anzeiger*, Bd. vii., 1892.
[5] 'Die Bezahnung der Zahnwale,' *Denkschr. d. med. naturw. Gesellsch.* Bd. xxviii., 1893.
[6] 'The Evolution of the Teeth in the Mammalia,' *Jour. Anat. and Phys.*, Bd. xxvii., 1903.
[7] *American Naturalist*, 1883.
[8] *Evolution of the Mammalian Teeth*, 1907.

PHARYNX.

The **pharynx** (figs. 54 and 55) extends from the base of the skull to the lower border of the sixth cervical vertebra, where it terminates by becoming continuous with the œsophagus. It lies in front of the basilar part of the occipital bone and the upper six cervical vertebræ and behind the nasal cavities, mouth, and larynx. It may therefore be divided into three parts: namely—nasal, oral, and laryngeal. The velum palatinum or soft palate projects backwards and downwards into it, and

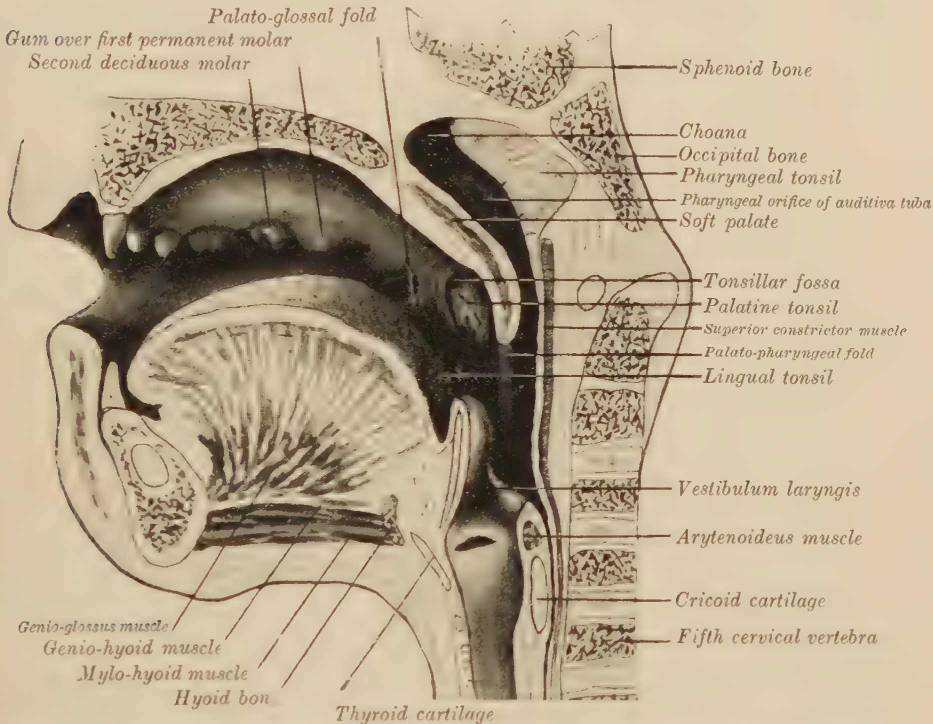


FIG. 54.—MEDIAN SECTION OF PART OF HEAD AND NECK OF A BOY AGED THREE YEARS, WITH MANDIBLE DEPRESSED. (J. Symington.)

during the act of deglutition is drawn upwards and backwards against its posterior wall, so as completely to separate the nasal from the oral portion. In all, seven openings lead into the cavity of the pharynx: namely—above the velum, the two *choanæ* (posterior nares), and the two tubæ auditivæ (Eustachian tubes); and below the velum, from above downwards, the orifices leading into the mouth, larynx, and œsophagus. The pharynx is about 14 cm. in length. Its transverse diameter is considerably greater than its antero-posterior. Its widest part (about 4 cm.) is usually opposite the upper part of the arytenoid cartilages (see fig. 59), below which it rapidly contracts, like a funnel, towards its termination, where it is narrowest.

The **nasal part of the pharynx** (*pars nasalis pharyngis, naso-pharynx*, or *post-nasal space*) is an air-cavity irregularly cubical in shape, and presents for examination an anterior, a posterior, and two lateral walls, a roof, and a floor. The anterior wall is bounded medially by the posterior edge of the nasal septum, and on each side of this septum is an opening (choana) into the corresponding nasal cavity. The posterior wall is continuous, below, with the

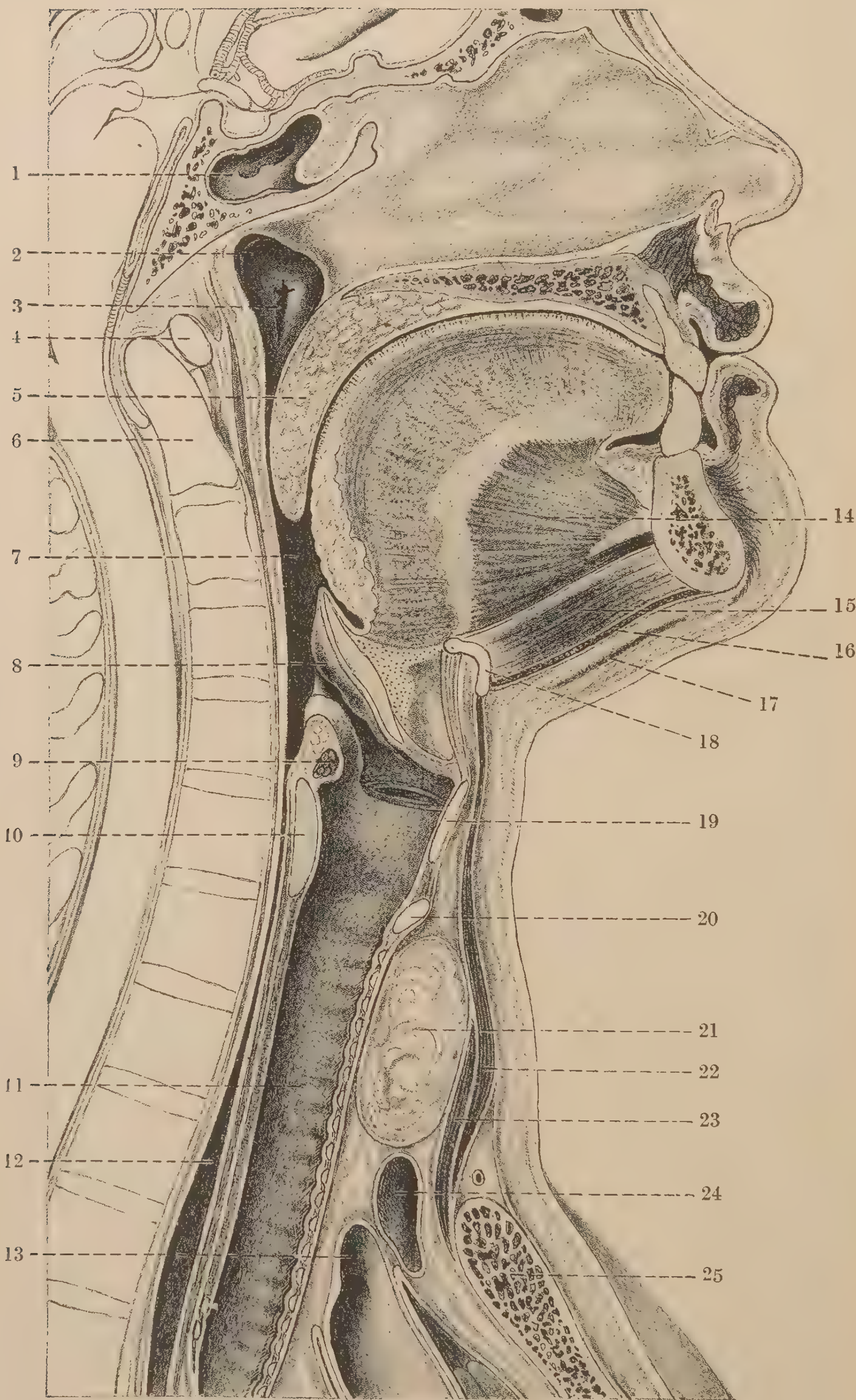


Fig. 55.

posterior wall of the oro-pharynx, and, above, with the vaulted roof, without any definite boundaries; but it may be conveniently regarded as reaching from the upper border of the superior constrictor of the pharynx, opposite the middle of the basi-occipital bone downwards to the lower border of the body of the axis vertebra.

In each lateral wall, the opening of the *tuba auditiva* appears as a vertical cleft, or as a funnel-shaped opening, and is bounded behind by a prominence—the *cushion*

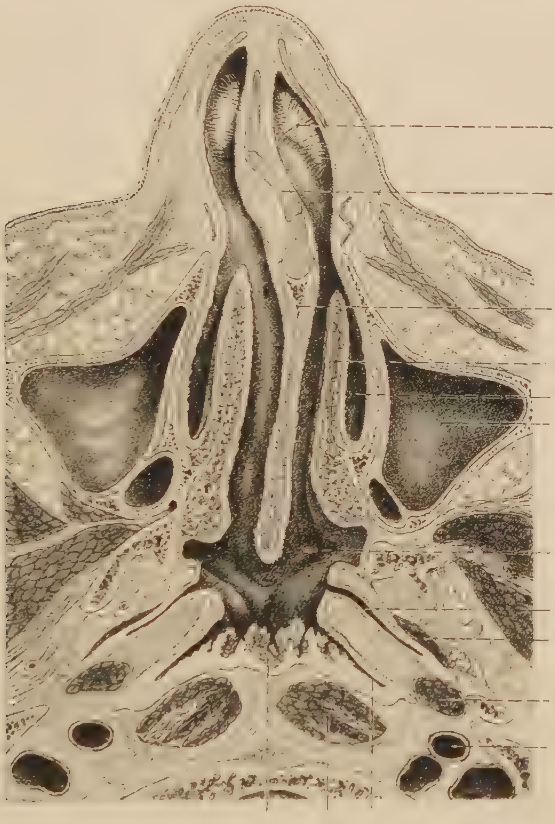


FIG. 56.—HORIZONTAL SECTION THROUGH NASAL CAVITIES AND NASAL PORTION OF PHARYNX, SEEN FROM ABOVE. Seven-eighths natural size. (J. Symington.)

1, naris; 2, septal cartilage; 3, vomer; 4, inferior concha; 5, inferior meatus; 6, maxillary antrum; 7, choana; 8, tuba auditiva or Eustachian tube; 9, tensor palati; 10, levator palati; 11, internal carotid artery; 12, lateral recess of pharynx; 13, longus capitis muscle; 14, pharyngeal tonsil.

of the Eustachian orifice—containing the cartilage of the tube. Between this prominence and the posterior wall of the pharynx, there is a deep recess passing backwards and outwards. It is known as the *lateral recess of the pharynx* (*recessus pharyngeus* [*Rosenmuelleri*]). From the cushion of the Eustachian orifice, the

FIG. 55.—MEDIAN SECTION OF THE HEAD AND NECK. Two-thirds natural size. (Braune.)

1, sphenoidal sinus; 2, lateral recess of pharynx; 3, pharyngeal orifice of tuba auditiva; 4, anterior arch of atlas; 5, soft palate; 6, body of axis; 7, oral portion of pharynx; 8, epiglottis; 9, arytenoid muscle; 10, cricoid cartilage; 11, trachea; 12, œsophagus; 13, origin of innominate artery from aorta; 14, genio-glossus muscle; 15, genio-hyoid muscle; 16, mylo-hyoid muscle; 17, platysma; 18, hyoid bone; 19, thyroid cartilage; 20, cricoid cartilage; 21, isthmus of thyroid body; 22, sterno-hyoid; 23, sterno-thyroid; 24, left innominate vein; 25, manubrium sterni.

mucous membrane forms a vertical fold—the *plica salpingo-pharyngea*—passing downwards on the side wall of the pharynx behind the *arcus pharyngo-palatinus.*

J. E. Frazer ('The Early Development of the Eustachian Tube and Naso-pharynx,' *Brit. Med. Jour.*, October 15, 1910) has shown that the Eustachian tube represents the fusion of the first, second, and possibly the third pharyngeal clefts, and the fossa of Rosenmüller owes its depth mainly to the prominence of the Eustachian tube, and is not derived from any of the pharyngeal clefts.

The floor of the naso-pharynx is formed by the upper surface of the soft palate, which slopes obliquely downwards and backwards. Behind the lower part of the soft palate, the naso-pharynx communicates with the oro-pharynx by a transverse slit. When the elevator muscles of the palate are thrown into action, this opening

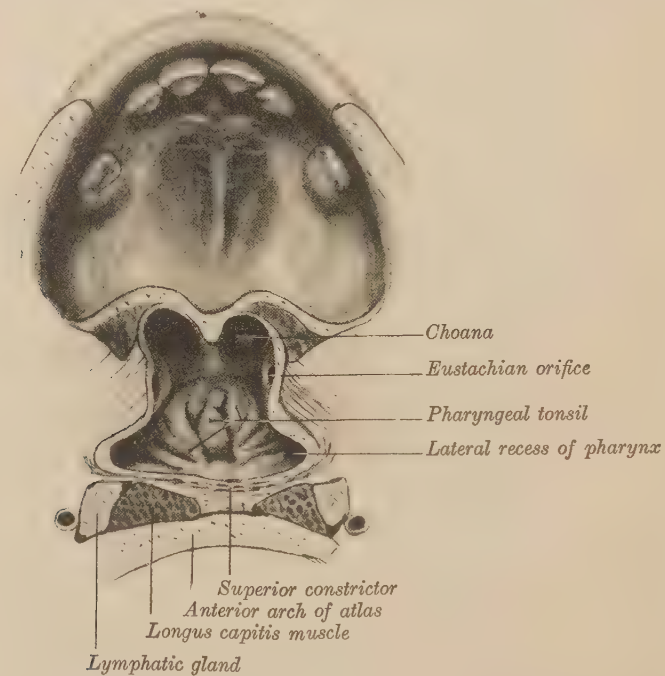


Fig. 57.—View of the pharyngeal tonsil, from below, in a child aged one year and six months. Natural size. (J. Symington.)

A horizontal section of the head was made at the level of the angles of the mouth, and the soft palate cut away.

is closed, and the upper surface of the palate may bulge upwards so as to be visible from the nasal cavities as the levator cushions. This condition is sometimes met with in the dead body.

The roof or vault of the pharynx lies below the upper part of the basi-occipital and posterior part of the basi-sphenoid portion of the base of the skull. It is separated from the lateral wall on each side by a groove continuous posteriorly with the pharyngeal recess or fossa of Rosenmüller, and anteriorly it extends to the nasal septum and the roof of the choanæ.

Tonsilla pharyngea.—The mucous membrane of the roof of the pharynx is thrown into folds and infiltrated with lymphoid tissue, forming the pharyngeal tonsil (see figs. 54, 56, and 57). In the median line, at about the union of the roof and posterior wall of the naso-pharynx, a recess is almost invariably found, which may end blindly after a short course, or may turn forwards for some distance

in the roof of the pharynx. This bursa is known as Luschka's pouch ('Der Schlundkopf des Menschen,' 1868, p. 26). Its developmental significance is unknown, and it does not appear to be specially associated with the formation of the pharyngeal tonsil. From the neighbourhood of this pouch, a number of folds radiate outwards and forwards over the roof of the pharynx. The number and position of the folds, and of the deep fissures separating them, vary somewhat. Thus a median fold may pass forwards from the pharyngeal bursa towards the nasal septum, or a fissure may extend from the bursa so as to divide the pharyngeal tonsil into two lateral halves. The fissures passing forwards often form curves with their convexity outwards, while those near the base of the tonsil are generally straight and nearly transverse.

The upper or attached surface of the pharyngeal tonsil is united to the fibrous tissue covering the basi-occipital and basi-sphenoid, and its free surface looks towards the upper two-thirds of the soft palate.

The pharyngeal tonsil is distinctly visible to the naked eye during the later months of fetal life, and it continues to increase in size during infancy and early childhood. Possibly, it normally attains its maximum development by the sixth or seventh year, after which it gradually atrophies. It occasionally persists in a well-developed condition until adult life. In a boy aged three years (see fig. 54), the distance from the cranial periosteum, where the tonsil was attached, to the posterior surface of the soft palate was 15 mm., and this space was about equally divided between the tonsil and the cavity of the pharynx. This does not represent, in my experience, an excessive growth for a child of about this age. It is sometimes so much hypertrophied that it nearly reaches the soft palate, and, with the mucous that generally collects in such cases in the naso-pharynx, it may almost entirely prevent nasal breathing (see Symington, 'The Pharyngeal Tonsil,' *British Medical Journal*, October 15, 1910).

The average capacity of the nasal part of the pharynx is said to be 14 c.c. Its transverse diameter in front of the Eustachian orifices is about 22 mm.; between the Eustachian cushions it varies considerably—on an average it is about 15 mm.: and between the outer ends of the fossæ of Rosenmüller about 3 cm. The distance from the lower part of the posterior edge of the nasal septum to the posterior wall of the pharynx is 15 mm.

The **oral part of the pharynx** (pars oralis pharyngis) is situated below the soft palate and above the level of the larynx. Owing to the mobility of the tongue and of the soft palate, it varies considerably in size and form. It communicates in front with the mouth through the *isthmus faucium*, and below this opening it is bounded anteriorly by the posterior part of the dorsum of the tongue. Its posterior wall is usually in front of the third cervical vertebra, and, when the soft palate is raised, also in front of the lower part of the body of the axis vertebra. On each lateral wall, there is a somewhat triangular recess, bounded by two folds of mucous membrane—the *arcus palato-glossus* (anterior palatine arch) and the *arcus palato-pharyngeus* (posterior palatine arch). The anterior arch joins the tongue and forms the lateral boundary of the isthmus of the fauces, while the posterior one gradually disappears on the side wall of the pharynx.

The **tonsillæ palatinæ** are two oval masses of lymphoid tissue, situated one on each side in the recess between the anterior and posterior palatine arches. Their long axes are directed from above downwards and somewhat backwards, and they reach from the soft palate above to the side of the tongue below. When the fauces are closed, the free surface of each tonsil lies against the posterior part of the tongue (see fig. 20). On an average, they measure at puberty 20 mm. to 25 mm. in a vertical direction, 10 mm. to 15 mm. from before backwards, and from 5 mm. to 10 mm.

from within outwards. They are frequently enlarged in children and atrophied in adults, and they vary greatly not only in size, but also in appearance. Hett and Butterfield[1] found that the tonsils in healthy children begin to atrophy about the fifth year. When viewed from the median aspect, the tonsil is seen to occupy a recess (*sinus tonsillaris*), which is bounded above and in front by a crescentic fold of mucous membrane, strengthened by fibrous tissue continuous with the capsule of the tonsil. The upper part of this fold, known as the *plica supra-tonsillaris*, is well marked and forms the median boundary of a recess, generally known as the *fossa supra-tonsillaris*,

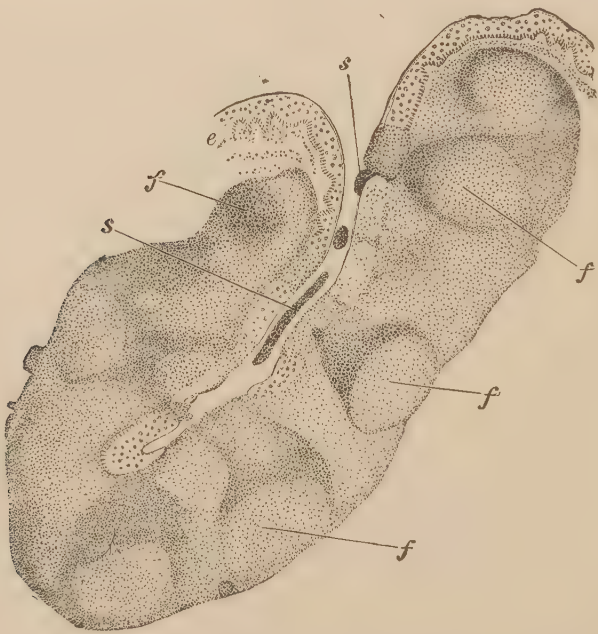


FIG. 58.—SECTION THROUGH ONE OF THE CRYPTS OF THE TONSIL. Magnified. (Stöhr.)

e, stratified epithelium of general surface, continued into crypt ; *f*, *f*, follicles or nodules of lymphoid tissue ; opposite each nodule, or germ-centre, numbers of lymph-cells are passing into and through the epithelium ; *s*, *s*, masses of cells which have thus escaped from the tonsil to mix with the saliva as salivary corpuscles.

which extends forwards and upwards into the tonsil for a depth of 5 mm. to 10 mm. ; the lower part of the fold which bounds the tonsillar recess anteriorly, is called the *plica triangularis*, as it forms the boundary of a triangular area limited in front by the anterior palatine arch, and below by the tongue. On dissection or section, the tonsil is found to be more extensive than the floor of the depression ; thus it extends upwards around the supra-tonsillar fossa and also forwards external to the plica triangularis as far as the anterior palatine arch.

The tonsil is provided with a well-defined capsule, from the inner aspect of which septa pass into the organ. The outer surface of the capsule, in the greater part of its extent, is united with neighbouring structures by a rather loose areolar tissue containing a venous plexus. This peri-tonsillar space is easily demonstrated laterally and above, where the tonsil lies against the median surface of the superior constrictor, and also over the anterior part of its median aspect where it is covered

[1] 'The Anatomy and Comparative Anatomy of the Palatine Tonsil, and its Rôle in the Economy of Man,' *Brit. Med. Jour.*, September 20, 1913.

by the mucous membrane of the plica triangularis. In front, however, the capsule is united by firm fibrous tissue to the palato-glossus muscle, behind to the palato-pharyngeus muscle, and below it is continuous with the fibrous tissue of the tongue. Both the external and internal carotid arteries lie fully an inch lateral and posterior to the tonsil. The tonsil lies median to the lower border of the mandible, a little in front of its angle; but it is separated from the skin by the submandibular gland, stylo-glossus, stylo-pharyngeus, and superior constrictor muscles (see fig. 20), and is too deeply placed to be felt externally, even when enlarged—more especially since it then bulges inwards and not to any appreciable extent outwards.

The free surface of the tonsil exhibits a number of deep depressions and clefts (*fossulæ tonsillares*), some of which reach outwards nearly as far as the capsule. The walls of these clefts, as well as the surface of the gland, are infiltrated with lymphoid tissue. The fissures on the upper part of the tonsil open into the supra-tonsillar fossa.

Blood-vessels, lymphatics, and nerves.—Arteries.—The tonsils receive a large supply of blood from a number of small arteries. The principal supply is from the tonsillar and palatine branches of the external maxillary, which pierce the superior constrictor and enter the lower and posterior part of the gland. The descending palatine of the internal maxillary sends twigs to the upper part, and the dorsalis linguæ to the lower end. From these arteries, fine branches and capillaries are distributed abundantly to the lymphoid tissue and follicles and to the papillæ of the mucous membrane which lines the recesses. The **veins** are numerous, and enter the tonsillar plexus on its outer side. **Lymphatics** are abundant, and surround the follicles with a close plexus; the vessels pierce the superior constrictor muscle and pass to one or more glands lying close to the posterior belly of the digastric muscle and the internal jugular vein (superior deep cervical group of glands). The **nerves** come from the glosso-pharyngeal, and from the trifacial.

According to Hett and Butterfield,[1] in infancy, the portion of the tonsil situated in the walls of the supra-tonsillar recess (palatine portion of the tonsil) is well developed, and forms about a third of the organ; but during childhood it tends to atrophy, and there is a marked development of lymphoid tissue opposite the tonsillar depression, so that the main part of the tonsil is found below the supra-tonsillar fossa. They found that the simplest form of mammalian tonsil was a funnel surrounded by lymphoid tissue, and they consider that the lymphoid tissue in the wall of the supra-tonsillar fossa is an integral part of the human tonsil. In addition to the paper of Hett and Butterfield, one by J. Killian ('Entwickelungsgeschichte, anat. und klin. Untersuchungen ueber Mandelbucht und Gaumenmandel,' *Arch. f. Laryngologie*, Bd. vii., 1898) may be consulted for further particulars regarding the anatomy of the tonsil. Objection has been raised to the term *supra-tonsillar fossa*, since the recess lies within the capsule of the tonsil, and hence is not as the term suggests, situated above the tonsil. The name tonsillar fossa would be more accurate.

The depression forming the sinus tonsillaris is the remains of the dorsal end of the median part of the second pharyngeal cleft. In the third month of fetal life the sinus is subdivided into two recesses by an intra-tonsillar fold (Hammar). From each of these recesses, processes extend laterally, and have lymphoid tissue developed in their walls, so that each tonsil consists of an anterior and upper and a posterior and lower portion. The fold separating these two parts of the tonsil subsequently disappears, but traces of it may sometimes be recognised in the adult.

The **laryngeal part of the pharynx** (pars laryngea pharyngis) (figs. 13, 59, and 60) is situated behind the entire extent of the larynx. Its length is equal to that of the nasal and oral parts combined. In the upper part of its anterior wall is the superior aperture of the larynx. On either side of this is a longitudinal groove called the *recessus pyriformis*, which represents the remains of the fourth

[1] 'The Anatomy of the Palatine Tonsil,' *Jour. Anat. and Phys.*, vol. xliv., October 1909.

visceral cleft (His). This recess (see fig. 59) commences below the lateral glosso-epiglottic fold, and ends opposite the cricoid cartilage. It is deepest about the middle, gradually becoming shallower above and below. In a horizontal section, it has a somewhat triangular form (see fig. 59), with lateral and median walls, and a base directed backwards towards the posterior pharyngeal wall. The mucous membrane on its lateral wall covers the posterior part of the thyro-hyoid membrane and the upper and posterior part of the lamina of the thyroid cartilage, while that on the median wall is in relation with the aryepiglottic fold, the arytenoid, corniculate, and cuneiform cartilages, the ventricular fold, and the ventricle and its appendix.

Opposite the laryngeal aperture, the transverse diameter of the pharynx is about 4 cm. A little below this opening, the anterior and posterior walls of the pharynx come in contact, but the transverse diameter undergoes only a very slight

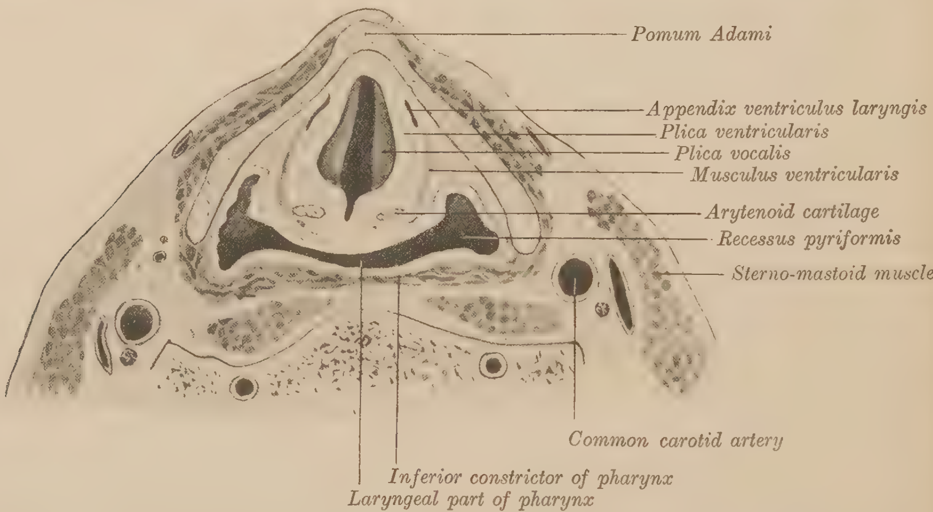


FIG. 59.—HORIZONTAL SECTION THROUGH THE UPPER PART OF THE LARYNGEAL PORTION OF THE PHARYNX, ETC., OF AN ADULT MALE. Natural size. (J. Symington.)

diminution as far down as the cricoid cartilage, behind which it rapidly contracts so that at its termination it is only about 12 mm. to 16 mm. broad. The part of the pharynx behind the cricoid cartilage being normally a closed cavity, and, only opening during deglutition, cannot be seen with the laryngoscope unless the larynx be drawn forwards.

Structure of the pharynx.—The walls of the pharynx are formed from within outwards of a mucous membrane, a layer of fibrous tissue called the *pharyngeal aponeurosis*, a muscular coat, and another layer of fibrous tissue, which with that covering the buccinator muscle, is called *bucco-pharyngeal fascia*. The pharyngeal aponeurosis is thin and lax below, but becomes thicker and denser above, where it is attached to the posterior part of the sphenoid bone and passes outwards to the petrous portion of the temporal bone and on to the auditory tube. It is strengthened in the middle line by a strong band descending between the longi capitis muscles from a part of the basilar process of the occipital bone, which often presents a marked tubercle.

Behind, the bucco-pharyngeal fascia is connected by a very loose areolar tissue to the pre-vertebral fascia, covering the bodies of the cervical vertebra and the muscles which rest upon them. At the sides, it has similar connections with the

styloid process and its muscles, and with the sheaths of the large vessels and nerves of the neck.

The attachments and relations of its muscular coat will be described in Vol. IV.

The mucous membrane of the pars nasalis is of a deeper red colour than that below the soft palate, except over the nasal septum, where it is very pale, and at the orifices of the auditory tubes, which are yellowish. The pars nasalis is covered with ciliated epithelium, while the pars oralis and the pars laryngea have stratified squamous epithelium. The ducts of numerous mucous glands open on the surface; the glands are specially abundant in the soft palate, round the orifice of the Eustachian tube, and on the posterior part of the tongue. The pharyngeal, palatine, and lingual tonsils have already been described. According to Waldeyer,

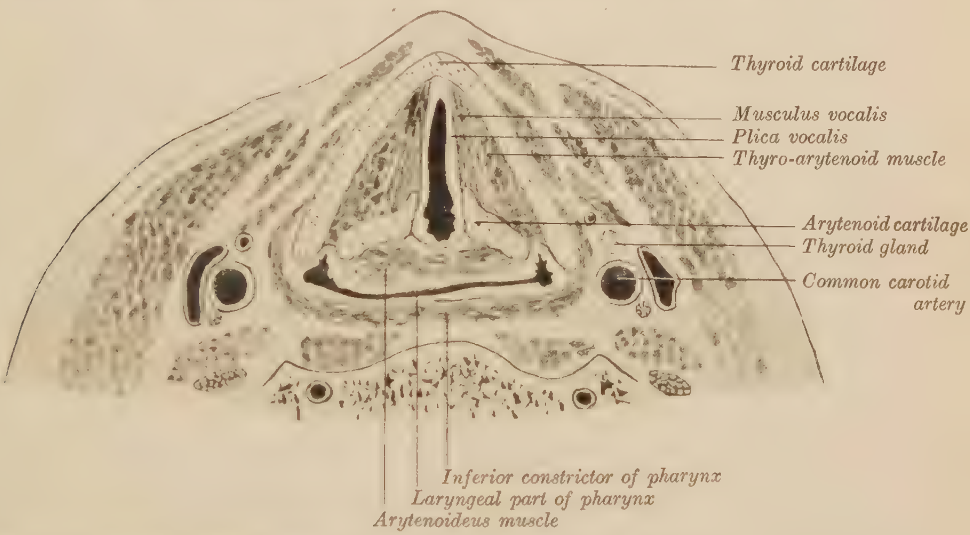


FIG. 60.—HORIZONTAL SECTION THROUGH THE LARYNGEAL PART OF THE PHARYNX OF AN ADULT MALE. Natural size. (J. Symington.)

The section is opposite the base of the arytenoid cartilages and is viewed from above.

these form part of a ring of lymphoid tissue encircling the pharynx. From the pharyngeal tonsil, the lymphoid tissue passes round the opening of the auditory tube (tubal tonsil), then downwards over the soft palate to the palato-pharyngeal arch, and forwards to the palatine tonsil, from which it crosses the tongue as the lingual tonsil to the opposite palatine tonsil, and thence up to the pharyngeal tonsil.

Blood-vessels, lymphatics, and nerves.—The pharyngeal wall is supplied by numerous branches derived directly or indirectly from the external carotid **artery**: namely—the ascending pharyngeal, the superior laryngeal branch of the superior thyroid, the dorsales linguæ of the lingual, the ascending palatine and tonsillar of the external maxillary, and the descending palatine of the internal maxillary. The **lymphatics** of the soft palate and the palatine tonsils have already been described in connexion with the account of these structures. The lymphatics of the rest of the pharynx form a rich submucous plexus, from which two sets of vessels arise on each side. The upper set ends in a gland (see fig. 3) situated behind the superior constrictor muscle and in front of the longus capitis muscle. An infection of this gland is stated to be a common cause of retro-pharyngeal abscess. The lower set of vessels converges towards the thyro-hyoid membrane, which they pierce to end in the glands placed in front of the bifurcation of the common carotid

artery. The **veins** form a peripharyngeal plexus on the posterior and lateral walls of the pharynx, and from this plexus the blood passes into the internal jugular veins. The sensory **nerves** of the pharynx are derived from the maxillary division of the trifacial, the great superficial petrosal of the facial, the glosso-pharyngeal, and the superior laryngeal of the vagus. The constrictor muscles of the pharynx are supplied by the pharyngeal and inferior laryngeal branches of the vagus.

Peculiarities according to age.—At birth, the posterior edge of the nasal septum is nearly horizontal, and the naso-pharynx has a very small vertical diameter; the oro-pharynx is opposite the interval between the basi-occipital and the anterior arch of the atlas, and the laryngo-pharynx is in front of the upper four cervical vertebræ. This high position of the pharynx is due to the relatively small vertical extent of the facial part of the skull. As this part of the skeleton gradually attains its adult proportions, the palate, tongue, larynx, and pharynx descend until the lower ends of the pharynx and larynx are opposite the lower border of the sixth cervical vertebra—a difference of two vertebræ and two intervertebral disks as compared with their position at birth. The descent is very gradual, and is not completed until after puberty.

Varieties.—The principal variations of the pharynx are due to the abnormal persistence of the visceral clefts or irregularities in their position. Various cases of this have been described as pharyngeal diverticula or cervical fistulæ (see K. von Kostanecki, 'Zur Kenntnis der Pharynxdivertikel des Menschen mit besonderer Berücksichtigung der Divertikelbildungen im Nasenrachenraum,' *Virchow's Archiv*, Bd. cxvii., 1889).

TUBUS DIGESTORIUS.

The portion of the alimentary canal extending from the commencement of the œsophagus to the anus is known as the **tubus digestorius.** The lumen

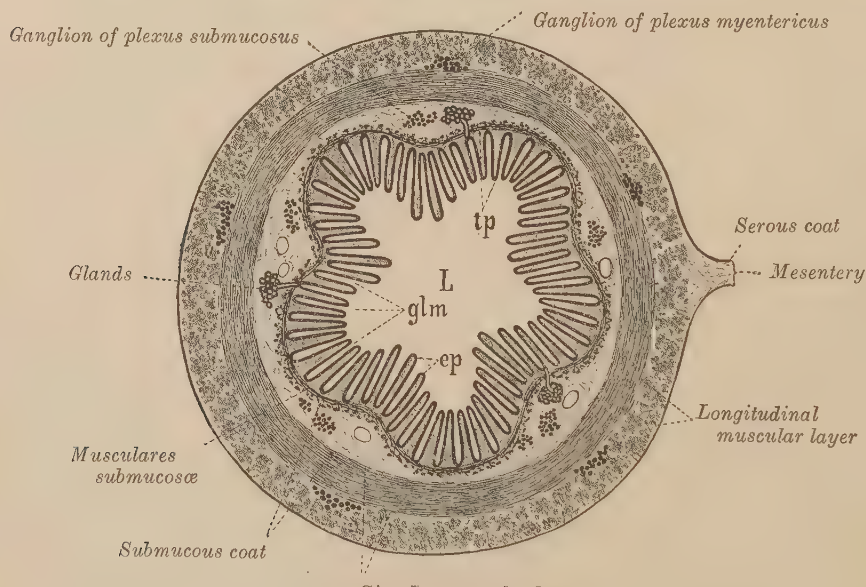


Fig. 61.—Diagram of section of tubus digestorius. (Sobotta.)

of this tube is bounded by a wall composed from within outwards of a mucous membrane (*tunica mucosa*), a layer of loose areolar tissue (*tela submucosa*), and a muscular coat (*tunica muscularis*). Along the greater length of the tube there is in addition a serous coat (*tunica serosa*), derived from the peritoneum (fig. 61). This serous coat is united to the muscular coat by a small amount of areolar tissue (*tela subserosa*). Where the serous coat is absent, a layer of connective tissue forms an external investment (*tunica adventitia*).

ŒSOPHAGUS.

The **œsophagus** or **gullet** is the part of the alimentary canal leading from the pharynx to the stomach. It commences at the level of the lower border of the cricoid cartilage, opposite the disk between the sixth and seventh cervical vertebræ, and passes downwards through the lower part of the neck into the thorax. In this cavity it lies in the superior and posterior mediastina, and then piercing the diaphragm it enters the abdomen, and, after a very short course in this cavity, joins the stomach at the level of the eleventh thoracic vertebra. The œsophagus may therefore be divided into four parts—cervical, mediastinal or thoracic, diaphragmatic, and abdominal.

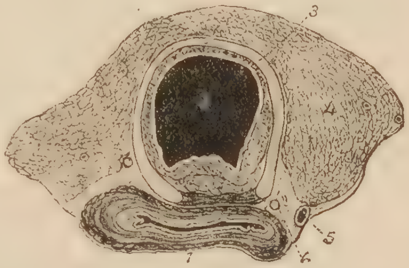


FIG. 62.—HORIZONTAL SECTION OF TRACHEA, ŒSOPHAGUS, AND THYROID BODY. (J. Symington.)

1, œsophagus; 2, cavity of trachea; 3, cartilaginous ring of trachea; 4, thyroid body; 5, inferior thyroid artery; 6, inferior laryngeal nerve.

Dimensions.—The length of the œsophagus is about 23 cm. to 25 cm. As the distance from the incisor teeth to the lower end of the pharynx is about 15 cm., the total length of the portion of the alimentary canal extending from these teeth to the cardiac orifice of the stomach is, on an average, about 40 cm. When empty, its greatest diameter is about 20 mm.; but when moderately distended, so that it acquires a

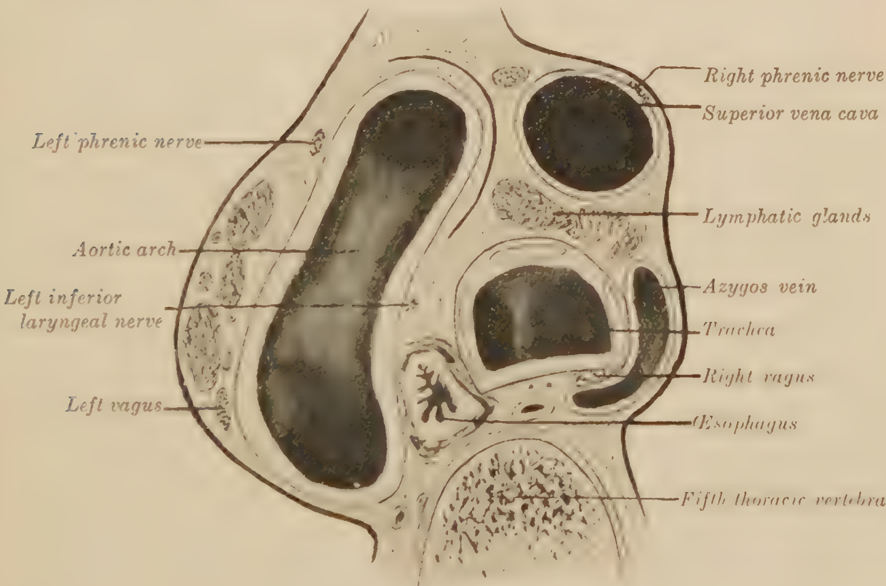


FIG. 63.—HORIZONTAL SECTION OF THE ŒSOPHAGUS, TRACHEA, AORTIC ARCH, ETC., AT THE LEVEL OF THE FIFTH THORACIC VERTEBRA, VIEWED FROM ABOVE. Natural size. (J. Symington.)

cylindrical form, its diameter varies from 18 mm. to 24 mm. The œsophagus is usually described as presenting three constrictions, with slight and elongated dilatations between them: the first constriction is at its commencement,

the second close to the bifurcation of the trachea, where the œsophagus lies against the aortic arch, and the third at the place where it pierces the diaphragm. It is usually flattened from before backwards, so that its lumen appears as a transverse slit (see fig. 62); but occasionally, for some little distance above the diaphragm, it is rounded with the cavity stellate in form (fig. 64).

Direction.—Its course is not quite vertical, but has three slight curvatures. One of these is in the sagittal plane, and corresponds with that of the front of the vertebral column as far down as about the seventh thoracic vertebra, where the œsophagus usually begins to leave the spine and pass in front of the aorta. Sometimes, however (as seen in figs. 170 and 171), the descending aorta lies against the left side of the vertebral column, and the œsophagus continues in close relation with the bodies of the vertebræ until the level of the eighth or ninth vertebra. The other two curvatures are in the coronal plane; for the œsophagus, commencing in the median line, inclines to the left side as it descends to the root of the neck; thence to the fifth thoracic vertebra it gradually resumes the median position; and finally, it deviates again to the left, at the same time coming forward towards the œsophageal opening of the diaphragm. After piercing the diaphragm, it turns abruptly towards the left side to join the stomach.

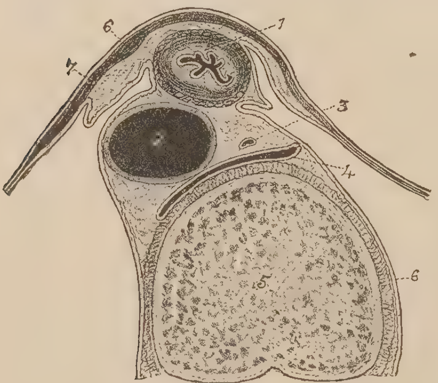


FIG. 64.—HORIZONTAL SECTION OF THE ŒSOPHAGUS AND THORACIC AORTA AT THE LEVEL OF THE NINTH THORACIC VERTEBRA. (J. Symington.)

1, œsophagus; 2, descending aorta; 3, thoracic duct; 4, vena azygos receiving a tributary from the left side; 5, body of vertebra; 6, pleura; 7, diaphragm.

Relations.—The only cervical vertebra behind the œsophagus is the seventh; but as the top of the sternum is opposite the upper border of the third thoracic vertebra the cervical part of the œsophagus is sometimes considered to be anterior to the last cervical and upper two thoracic vertebræ. It is connected with these bones and with the longus colli muscle by loose areolar tissue. At first the œsophagus lies directly behind the trachea, but, as it descends, it gradually inclines to the left, so that it projects to the left of the trachea, and has in front of it the left inferior laryngeal nerve, which is ascending on the side of the trachea to the larynx. The lateral relations of the upper part of the cervical portion of the œsophagus are the lateral lobes of the thyroid body (see fig. 62), the œsophageal branches of the inferior thyroid artery, and the inferior laryngeal nerves, with the common carotid arteries farther out. On the left side are also found the thoracic duct, left subclavian artery, and left pleura. In the thorax, the œsophagus is successively covered in front by the lower part of the trachea, by the commencement of the left bronchus, and by the heart and pericardium and the diaphragm. The aorta, except near the diaphragm, where the œsophagus is in front of the vessel, lies to the left, and the vena azygos (major) to the right and behind; the vagi nerves descend in close contact with its sides, and form a plexus around it, the left nerve proceeding gradually to the front, and the right nerve retiring behind it. In the superior mediastinum the left pleura lies close to its left side, while lower down, in the posterior mediastinum, the right pleura is in relation with its right side, and often extends inwards slightly behind it. Lastly, just before it pierces the diaphragm, the œsophagus is in contact with both pleuræ (fig. 64). The

posterior surface of the œsophagus is close to the bodies of the seventh cervical and upper seventh to tenth thoracic vertebræ, below which it passes to the front of the thoracic aorta. In about the mid-thoracic region, the thoracic duct ascends obliquely behind it from right to left.

On the right side, and near the lower end of the thoracic part of the œsophagus, may sometimes be found a small closed serous sac—the *bursa infra-cardiaca*—which represents the detached upper part of the recessus pneumo-entericus dexter (Broman, *Die Entwick. der Bursa Omentalis,* 1904).

STRUCTURES OF THE ŒSOPHAGUS.

The walls of the gullet are composed of three coats: namely—an external or muscular, a middle or areolar, and an internal or mucous coat. Outside the

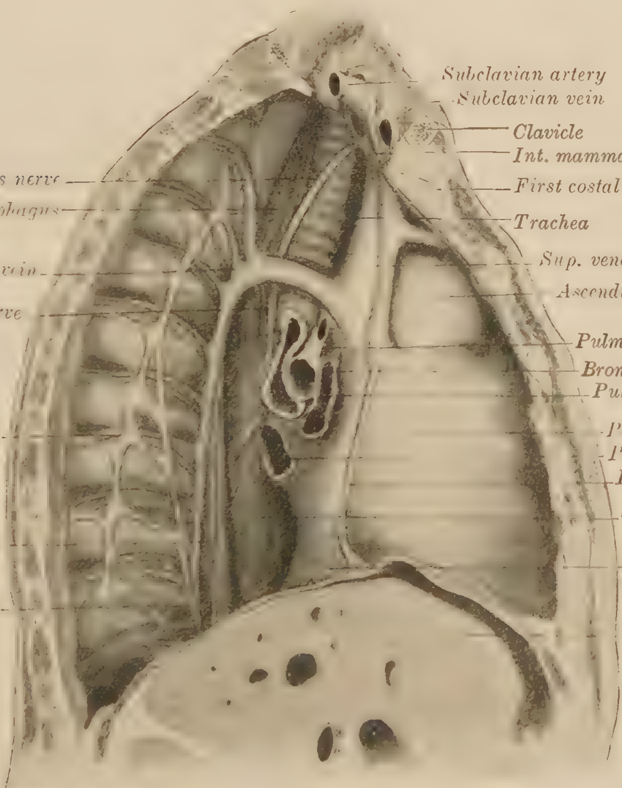


FIG. 65.—VIEW OF THE SEPTUM MEDIASTINALE FROM THE RIGHT LATERAL ASPECT. One-third natural size. (J. Symington.)

muscular coat there is a layer of loose areolar tissue with well-marked elastic fibres, which facilitate the distension and collapse of the œsophagus.

The **muscular coat** consists of an *external longitudinal layer* (seen in section in fig. 67, *b*), and an *internal* circular layer (*c*). This twofold arrangement of the muscular fibres prevails throughout the whole length of the alimentary canal: but the two layers are here much thicker, more uniformly disposed, and are more evident than in any other part of the digestive tube, except the anal canal. The external or longitudinal fibres arise by a flat tendon from the back of the cricoid

cartilage[1] at the prominent ridge between the posterior crico-arytenoid muscles, and its fibres spread out on the gullet as they descend, and soon form a continuous layer around the tube. Those fibres which are going to the back of the œsophagus wind round the side and join posteriorly about 2 cm. to 3 cm. below the cricoid cartilage, leaving a triangular area on the upper part of the posterior surface of the œsophagus, which is almost destitute of longitudinal fibres. Abel describes a corresponding area on the anterior surface of the œsophagus. Only a few of the longitudinal fibres join the inferior constrictor muscle. The internal or *circular*

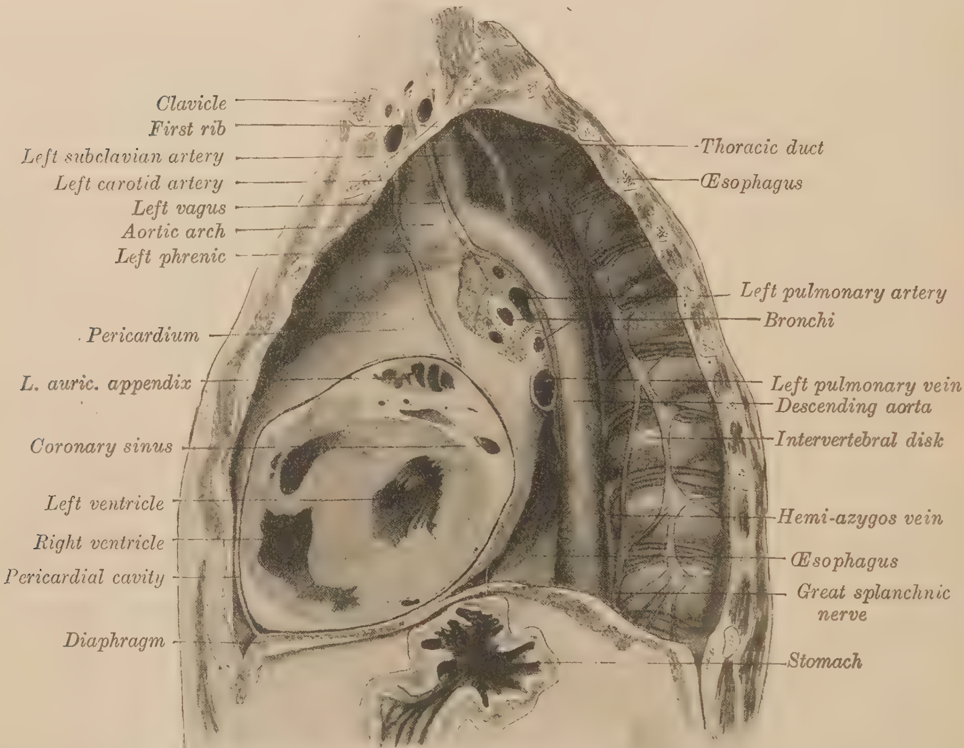


Fig. 66.—View of the septum mediastinale from the left lateral aspect. One-third natural size. (J. Symington.)

fibres are attached in front to the back of the cricoid cartilage, and partly blend with the lowest fibres of the inferior constrictor of the pharynx. The rings which they form around the tube have a horizontal direction at its upper and lower part, but in the intervening space are slightly oblique. At the lower end, both layers of fibres become continuous with those of the stomach.

The muscular coat of the upper end of the œsophagus is of a well-marked red colour, and consists wholly of striped muscular fibres; these are gradually replaced by plain muscular fibres, so that these are almost the only kind found in the lower half of the tube. A few striped fibres may, however, be found even at the lower end, and in some animals they preponderate throughout the whole length of the tube.

[1] Birmingham, 'A Study of the Arrangement of the Muscular Fibres of the Upper End of the Œsophagus,' *Jour. Anat. and Phys.*, vol. xxxiii. October 1898; and Williamina Abel, 'The Arrangement of the Longitudinal and Circular Musculature of the Upper End of the Œsophagus,' *ibid.*, vol. xlvii., July 1913.

The longitudinal fibres of the œsophagus are sometimes joined by a broad band of smooth muscle passing from the left pleura (m. pleuro-œsophagus), and sometimes also by another from the left bronchus (m. broncho-œsophagus). According to Cunningham ('Note on the Broncho-œsophageal and Pleuro-œsophageal Muscles,' *Jour. Anat. and Phys.*, vol. x., 1876), the former is almost constantly present, and the latter very frequently.

The **areolar** or **submucous** coat is placed between the muscular and mucous coats, and connects them loosely together. It exceeds the mucous membrane considerably in thickness, and in it are contained the mucous glands (fig. 67, *h*), which open on the mucous membrane.

The **mucous membrane** is of firm texture, and is paler in colour than that of the pharynx or stomach, and the whole is covered with a thick, stratified, scaly epithelium. From its loose connexions, its outer surface is freely movable on the muscular tunic; and under ordinary circumstances the mucous lining is thrown into longitudinal folds or rugæ, which are in mutual contact. These folds disappear on distension of the canal.

The small compound racemose or tubulo-racemose glands, named *œsophageal glands*, which are for the most part seated in the submucous tissue, are specially numerous at the lower end of the tube. A few of the smallest are situated in the substance of the mucous membrane. The cells of these glands are columnar. Their ducts are usually surrounded by collections of lymphoid tissue as they pass through the mucous membrane.

The mucous membrane is bounded next to the submucous coat by longitudinally disposed plain muscular fibres, which, imperfect above, form a continuous layer towards the lower end of the tube (*muscularis mucosæ*, *e*).

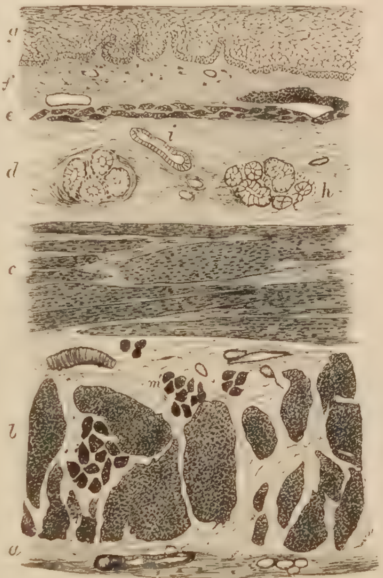


FIG. 67.—SECTION OF THE HUMAN ŒSOPHAGUS. Moderately magnified. (From a drawing by V. Horsley.)

The section is transverse, and from near the middle of the gullet. *a*, fibrous covering; *b*, divided fibres of the longitudinal muscular coat; *c*, transverse muscular-fibres; *d*, submucous or areolar layer; *e*, muscularis mucosæ; *f*, mucous membrane, with vessels and part of a lymphoid nodule; *g*, laminated epithelial lining; *h*, mucous gland; *i*, gland duct; *m′*, striated muscular fibres cut across.

Blood-vessels, lymphatics, and nerves.—The **arteries** of the œsophagus consist of a series of small vessels derived from the *inferior thyroid*, *descending aorta*, *left inferior phrenic*, and *left gastric*: these branches anastomose together. The **veins** pass to the *inferior thyroid*, *azygos*, and *coronary of stomach*; the submucous veins at the lower part of the œsophagus form a free communication between the portal and systemic veins, and become dilated in cases of obstruction to the circulation through the liver.

The **lymphatics** form plexuses in the submucous and muscular coats, and, after piercing the œsophageal wall, the vessels often run for some little distance longitudinally in the peri-œsophageal areolar tissue. The submucous plexus of the œsophagus is continuous with that of the pharynx above and the stomach below. The lymphatic vessels from the upper third of the œsophagus pass to the deep cervical and paratracheal glands, from the middle third to the bronchial and posterior mediastinal, and from the lower third to the cardiac. A small amount

of lymphoid tissue is present in the walls of the œsophagus, especially in the neighbourhood of the mucous glands. The **nerves** are derived from the inferior laryngeals, vagi, and sympathetic. The nerves form a gangliated plexus between the two layers of the muscular coat and also in the submucous coat.

Variations according to age.—At birth, the œsophagus is about 10 cm. long, and will admit of the passage of a catheter 5 mm. in diameter, while the distance from the alveolar border of the jaw to the cardia is about 17·5 cm. The œsophagus becomes gradually relatively shorter in relation to the vertebral column between birth and the twentieth year. This shortening is associated with the descent of the pharynx, and affects especially the cervical part of the œsophagus. The caudal end probably tends to sink in old age.

Varieties.—The upper part of the œsophagus, as a rare malformation, communicates with the trachea by a congenital fistula due to an arrest of the developmental process by which this part of the foregut becomes divided into an alimentary and a respiratory tube. This condition may be associated with an atresia of the upper end of the œsophagus. Diverticula occasionally occur, especially on the posterior wall, and the œsophagus may become considerably dilated just above the place where it pierces the diaphragm. When the heart is small and the lungs emphysematous, the mediastinal portion of the œsophagus may be displaced forwards and lie in a posterior mediastinal mesentery (see A. Keith, *Lancet*, March 7, 1903, and J. S. Dickey, *Applied Anatomy of the Lungs and Pleural Membranes*, 1911). According to Schaffer,[1] patches of the mucous membrane of the upper part of the œsophagus are frequently found, which resemble in structure the cardiac part of the stomach. An abnormal right subclavian artery may pass from left to right behind the œsophagus.

THE ABDOMEN AND PELVIS.

The portion of the digestive canal, situated beneath the diaphragm and consisting of the stomach and intestine, occupies, together with the liver and pancreas, the greater part of the abdomino-pelvic cavity. As this cavity also contains the spleen, the suprarenal glands, and the greater part of the genito-urinary organs—structures which have still to be described—it will be convenient at this stage to consider the external form of the abdomen and pelvis, the shape of their cavities, and the constitution of their walls.

ABDOMINO-PELVIC WALLS.

The abdomen and pelvis do not present definite external landmarks separating them from the thorax above and the inferior extremities below, as the skeletal walls of the thorax reach considerably below the level of the diaphragm, which divides the thoracic from the abdominal cavity, and numerous muscles belonging to the lower limbs arise from the superficial surface of the pelvic wall. Further, owing to the extension upwards of the ossa ilia on the lateral and dorsal aspects to a much greater height than the lower part of the abdominal cavity, the upper part of the gluteal, and other muscles of the lower limb, arising from the ilia, overlap the abdominal cavity. In the interval between the thoracic and pelvic walls, there is an area formed of muscular and connective tissue and devoid of any osseous support, except posteriorly, where the lumbar part of the vertebral column is found. Viewed from the front, this area is of large size, and it owes its somewhat diamond-shaped outline to the thoracic wall extending much farther downwards at the sides than in front and to a corresponding ascent of the lateral pelvic wall. In this area is situated the anterior abdominal wall proper, which varies considerably in shape and appearance according to the degree of its protrusion or retraction, the amount of subcutaneous fat, and the extent of its muscular development.

[1] 'Die oberen kardialen Œsophagusdrüsen und ihre Entstehung,' *Arch. f. path. Anatomie*, Bd. 177, 1904.

A tendinous interval, known as the linea alba, extends in the median line from the sternum to the pubes, between the two recti muscles of the abdomen. The position of the linea alba may be marked in the living body by a furrow from the sternum to the umbilicus; below this, the groove becomes indistinct owing to the close approximation of the two recti muscles and the larger amount of fat in the lower part of the abdominal wall. At the upper end of the linea alba, the lower end of the body of the sternum can be felt between the sternal ends of the seventh costal cartilages. This point is at the level of the tenth thoracic vertebra; the ensiform process, which projects below it, may reach to the disk between the eleventh and twelfth thoracic vertebræ. The average position of the umbilicus is opposite the fourth lumbar vertebra, and the top of the pubic symphysis is at the level of the first or second piece of the coccyx.

The two recti muscles form prominences which are broader above than below, and are marked by three transverse grooves corresponding to the tendinous intersections (lineæ transversæ) of these muscles. The outer border of each rectus muscle is indicated by a depression called the linea semilunaris, which joins the thoracic wall opposite the eighth costal cartilage.

Between the semilunar lines in front and the depressions external to the erectores spinæ behind, the abdominal wall is formed on each side mainly by the three muscular sheets, known as the external oblique, internal oblique, and the transverse muscles of the abdomen. This part of the trunk is usually slightly constricted, and forms the waist. The vertical extent of the non-skeletal part of the abdominal wall is least on each side between the tenth or eleventh costal cartilages above and the iliac crest below; and here, as a rule, it corresponds to the level of the bodies of the third and fourth lumbar vertebræ.

Posteriorly, the lumbar vertebræ, with the erector spinæ, quadratus lumborum, and psoas muscles on each side, form a broad thick mass, which effectually prevents any palpation of the abdominal organs or direct surgical access to the abdominal cavity within a region bounded by the lateral borders of the two erectores spinæ.

ABDOMINO-PELVIC CAVITY.

The abdomino-pelvic cavity is a large space, bounded by walls composed of muscular and connective tissue, and supported in certain situations by osseous elements. The cavity contains the abdomino-pelvic viscera, numerous blood-vessels, and a large serous sac known as the peritoneum. A layer of connective tissue, often infiltrated with fat, and, except in some places, a layer of parietal peritoneum, intervenes between the muscular wall and the contents of the cavity. The cavity is subdivided into two parts: an upper or larger part, the abdomen properly so called (*cavum abdominis*), and a lower or pelvic portion (*cavum pelvis*); the junction between these two divisions being marked circumferentially by the brim of the true pelvis. As the space below the plane of this brim is bounded to a large extent by rigid bony walls, while that above it readily admits of distension, the distinction between the two cavities is of great importance in connexion with the mechanism of pregnancy and child-birth. On the other hand, owing to the marked obliquity of the pelvis, by far the greater part of the pelvic cavity is situated above a horizontal plane corresponding to the top of the pubic symphysis, and is bounded in front by the anterior abdominal wall; so that for physical examination and operative work, a division of the abdomino-pelvic cavity into an abdominal and a pelvic portion is largely a theoretical one. Further, these two cavities communicate freely with one another; they have a common peritoneal space, and certain parts of the alimentary canal pass with facility from one to the other, while the bladder and

uterus may extend upwards into the abdomen. For these reasons, we will consider the two spaces together.

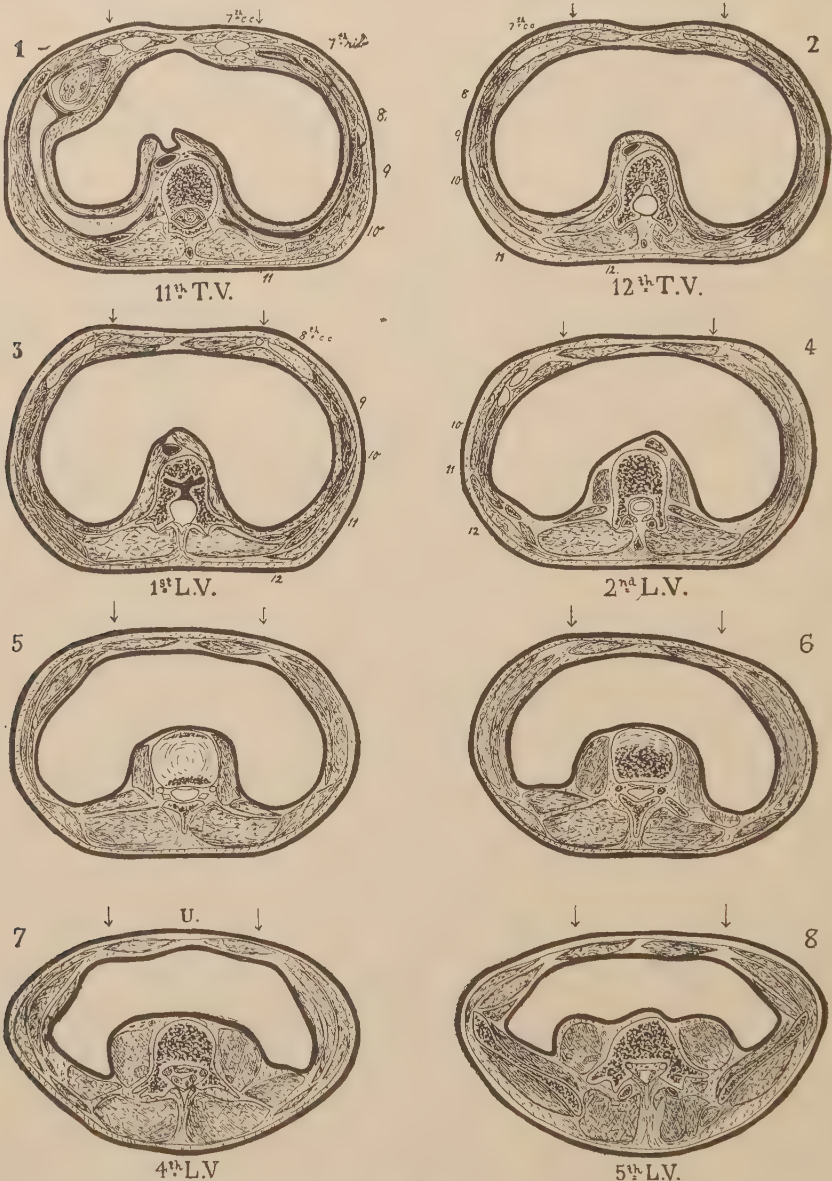


Fig. 68.

Figs. 68 and 68a.—A series of fourteen horizontal sections through the abdomen and pelvis of a man aged fifty years. (J. Symington.)

The sections are about 2·5 cm. apart; in each, only the wall is drawn, the cavity being left blank. They are viewed from above and reduced to one-sixth natural size. The arrows in front of each section indicate the position of the right and left lateral lines on the anterior abdominal wall. No. 5 section passed through the intervertebral disk between the second and third lumbar vertebræ; no. 6 through the disk between the third and fourth lumbar, and no. 9 through the disk between the fifth lumbar and first sacral.

As the walls of the abdomino-pelvic cavity vary greatly in thickness and in the extent to which they yield to changes in intra-abdominal pressure, the external form of the abdomen affords a very imperfect indication of the shape of its cavity.

The form of the abdomino-pelvic cavity may be demonstrated by serial sections in different planes; by hardening the contained viscera *in situ* and fixing them together after removal of the abdominal wall; or by taking moulds of the parietal surfaces of the viscera exposed over limited areas and making a cast from the various moulds. By the two last-mentioned methods we obtain preparations which are equivalent to casts of the cavity.

Shape illustrated by serial sections.—An examination of a series of horizontal sections (see figs. 68 and 68A) will show that towards the upper part of

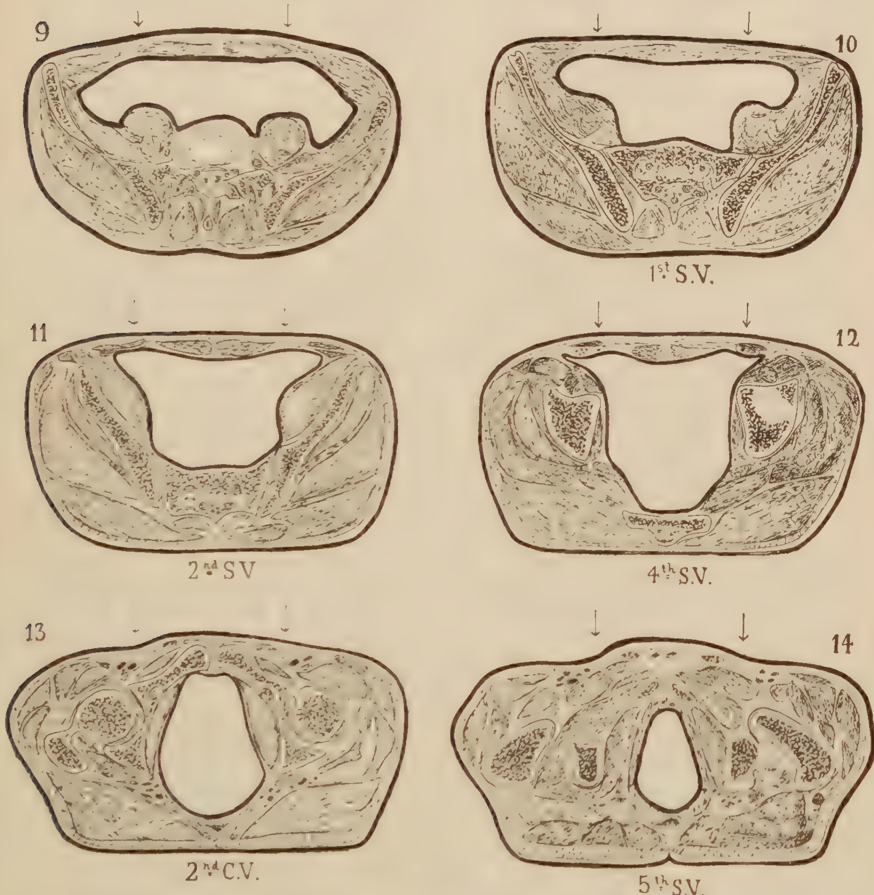


FIG. 68A.

the abdomen (2 and 3 of fig. 68) the cavity is kidney-shaped with the long axis transverse. The hilum, formed by the forward projection of the vertebral bodies, covered by the diaphragm, separates two deep hollows. The outline of the cavity becomes gradually modified from this level down to the last lumbar vertebra, owing mainly to the appearance and gradual increase of the psoas muscles, which lie one on each side of the bodies of the lumbar vertebræ. The mass projecting forwards towards the abdominal cavity, opposite the fourth and fifth lumbar vertebræ (7 and 8 of fig. 68), is fully double the breadth of that at the first lumbar. This increase tends to diminish the size of the abdominal cavity, and makes its outline somewhat crescentic. At the fifth lumbar (8 of fig. 68), the psoas muscles begin to pass laterally from the body of the vertebra; their separation from the

vertebral column is still more marked at the disk between the fifth lumbar and first sacral; while, opposite the upper part of the sacrum (11 of fig. 68A), they form with the iliac muscles the lateral walls of a recess bounded behind by the sacrum. From this level, downwards, the cavity rapidly alters in shape, its transverse diameter diminishing owing to the disappearance of the iliac fossæ, and the antero-posterior diameter increasing in consequence of the backward

Fig. 69.

Figs. 69 and 69a.—A series of four sagittal sections of the abdomen and pelvis of a man aged forty years. One-fourth natural size. (J. Symington.)

A, in the median plane; B, 3·5 cm., C, 6 cm., and D, 9 cm. to the left of the median plane. All the sections are viewed from the left lateral aspect.

slope of the sacrum. Below the level of the top of the pubic symphysis, the pelvic cavity becomes distinctly funnel-shaped, with the narrow end at the pelvic floor.

The posterior wall of the abdomen, and the boundaries of the pelvic cavity, being formed of bones and powerful muscles, do not yield to any appreciable extent to increased intra-abdominal pressure. On the other hand, the anterior abdominal wall being much thinner and almost destitute of any bony support, may be retracted

so as nearly to touch the front of the vertebral column or pushed forwards so as to become separated from it by a considerable interval (see fig. 70).

The four sagittal sections in figs. 69 and 69A illustrate the great vertical extent of the abdomino-pelvic cavity, as compared with its antero-posterior diameter, in a subject in which the anterior abdominal wall is slightly retracted between the sternum above and the pubes below. In this case, the cavity extends upwards in the median plane (A) to the level of the disk between the tenth and eleventh thoracic

FIG. 69A.

vertebræ, and downwards slightly beyond a line uniting the lower border of the pubic symphysis with the tip of the coccyx—a distance of 42 cm., while the median sagittal diameter is only 3 cm. at the umbilicus, 7 cm. opposite the twelfth thoracic vertebra, and has its maximum of 12 cm. at the level of the lower part of the sacrum. In section B, which is 3·5 cm. to the left of the median plane, the posterior abdominal wall is divided lateral to the bodies of the lumbar vertebræ, but through all their transverse processes. The cavity here has an hour-glass form somewhat similar to that in the median plane. The constriction of the cavity opposite the region of the umbilicus is due to the psoas muscle. Section C passes through the left lateral plane of the abdomen, which is 6 cm. from the median plane. The cavity is here triangular in outline, with its convex base above, and has a nearly vertical

anterior wall, and a posterior boundary, sloping obliquely from above downwards and forwards to meet the anterior wall at an acute angle a little above the inguinal (Poupart's) ligament. In this section, the part of the cavity above the upper transverse abdominal plane of Addison (*tp* in fig. 69) lies under cover of the thoracic wall, reaching to the level of the fifth costal cartilage in front and the lower border of the tenth rib behind. It is in this plane that the upper part of the abdominal cavity attains its maximum antero-posterior diameter, which here measured 13 cm. In section D, which passes through the nipple and about 2·5 cm. on the median side of the anterior superior iliac spine, the abdominal cavity presents the same general shape as in section C, but is smaller. The iliac fossa

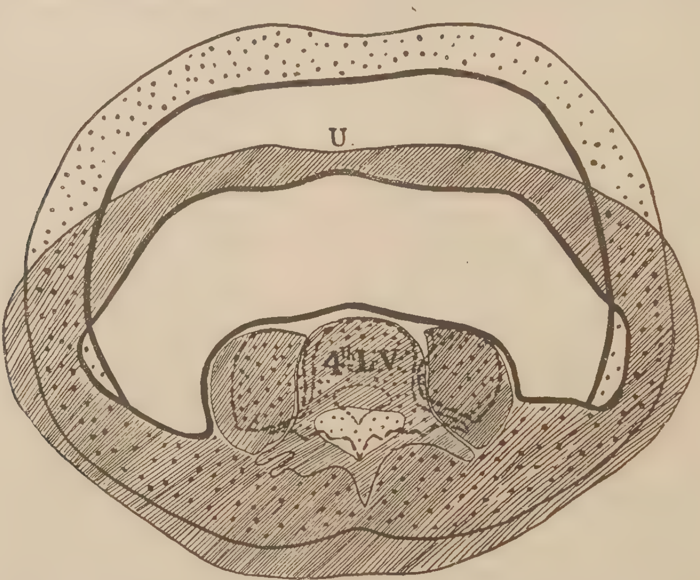


FIG. 70.—A HORIZONTAL SECTION OF A MAN, AGED FIFTY YEARS, AT THE LEVEL OF THE FOURTH LUMBAR VERTEBRA (NO. 7 OF SERIES IN FIG. 68) WITH A SECTION AT THE SAME LEVEL FROM EYCLESHYMER AND SCHOEMAKER'S 'CROSS-SECTION ANATOMY.' (J. Symington.)

The section of the man aged fifty is striped, and the other dotted; while both are reduced to the same scale.

is divided lateral to the psoas muscle and in front of the iliacus muscle. The section shows what a small antero-posterior diameter the abdominal cavity may have in this region.

We have already seen from two horizontal sections (fig. 70) that the abdominal cavity may be increased by a protrusion of the anterior abdominal wall; this increase is still more strikingly illustrated by a comparison of two median sagittal sections (see fig. 71), from which it may be seen that the lower part of the chest wall is also pushed forwards when the abdomen is distended.

The shape of the abdomino-pelvic cavity in a coronal section, passing anterior to the vertebral column, is shown in fig. 72. It illustrates the vaulted character of the roof, the degree to which the abdominal cavity extends upwards internal to the ribs, the comparatively narrow area at the sides between the ribs and the ilia, and the way in which the transverse diameter of the lower part of the abdomen is diminished by the ilio-psoas muscles.

Shape illustrated from contents.—The general form of the abdomino-pelvic cavity is well shown in specimens or casts of its whole contents (see figs. 73 to 75). The upper and larger portion of the mass occupying the abdomino-

pelvic cavity has its longest axis vertical, and under ordinary conditions its transverse diameter considerably exceeds its antero-posterior. Its outline, viewed from the front or the back, is irregularly quadrilateral, with sometimes a slight constriction about its middle; while seen from the right or left lateral aspects, it presents a triangular contour with the apex downwards. Continuous with the upper part of the contents mass is a lower and smaller portion which, viewed from the front or back, has a triangular outline with a blunt apex below, and

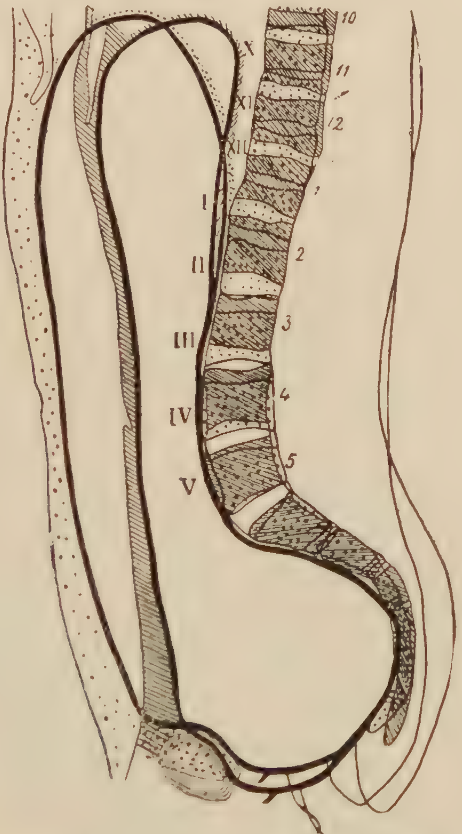


FIG. 71.—A MEDIAN SECTION OF A MAN AGED FORTY YEARS, AND A SECTION, IN THE SAME PLANE, OF A MAN AGED TWENTY-ONE YEARS. (Braune's *Topographische-anatomischer Atlas*, tab. 1, A.) Both drawings reduced to the same scale. (J. Symington.)

In the man aged forty, the vertebral column and anterior abdominal wall are striped, and arabic numerals placed behind the bodies of the lower thoracic and the lumbar vertebræ. In the man aged twenty-one, the vertebral column and anterior abdominal wall are dotted and roman numerals placed in front of the vertebræ.

from the sides is seen to be directed backwards and downwards, so that its axis forms an angle of about 60° with that of the upper portion of the mass.

The upper end of the mass is convex and closely applied to the concave under-surface of the diaphragm, and it must of necessity vary in form with the respiratory movements of this muscle. The anterior aspect may be concave, flat, or convex, according to the degree of retraction or protrusion of the anterior abdominal wall. The posterior aspect of the mass has a more constant and characteristic appearance than the anterior. A deep median groove extends from above downwards as far as the junction of the upper and lower portions of the abdomino-pelvic cavity, where it becomes continuous with a surface which is convex from above

FIG. 72.—CORONAL SECTION OF THE ABDOMEN AND PELVIS OF A BOY AGED TEN YEARS. One-third natural size. (J. Symington.)

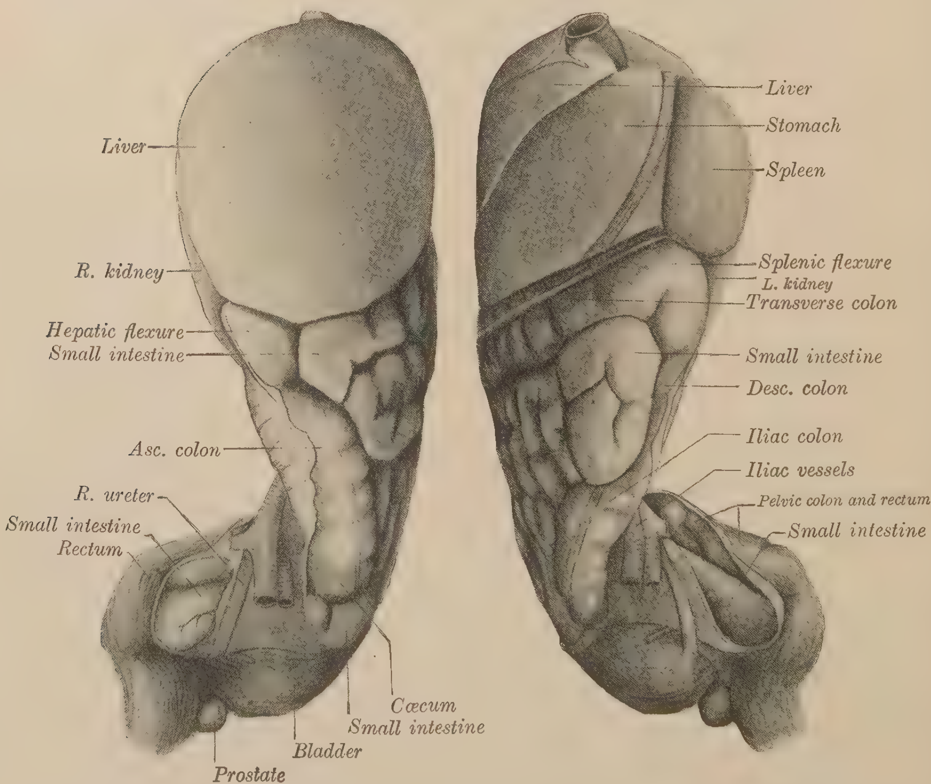


FIG. 73.—RIGHT AND LEFT LATERAL VIEWS OF THE ABDOMINO-PELVIC VISCERA OF A MALE AGED ABOUT FIFTEEN YEARS. Drawn from a model by His.

downwards and from side to side. The median groove broadens, and becomes shallower, as it descends and divides below into two lateral depressions, passing downwards and outwards. Median to these lateral grooves, the abdominal and pelvic contents become continuous with one another. On each side of the median

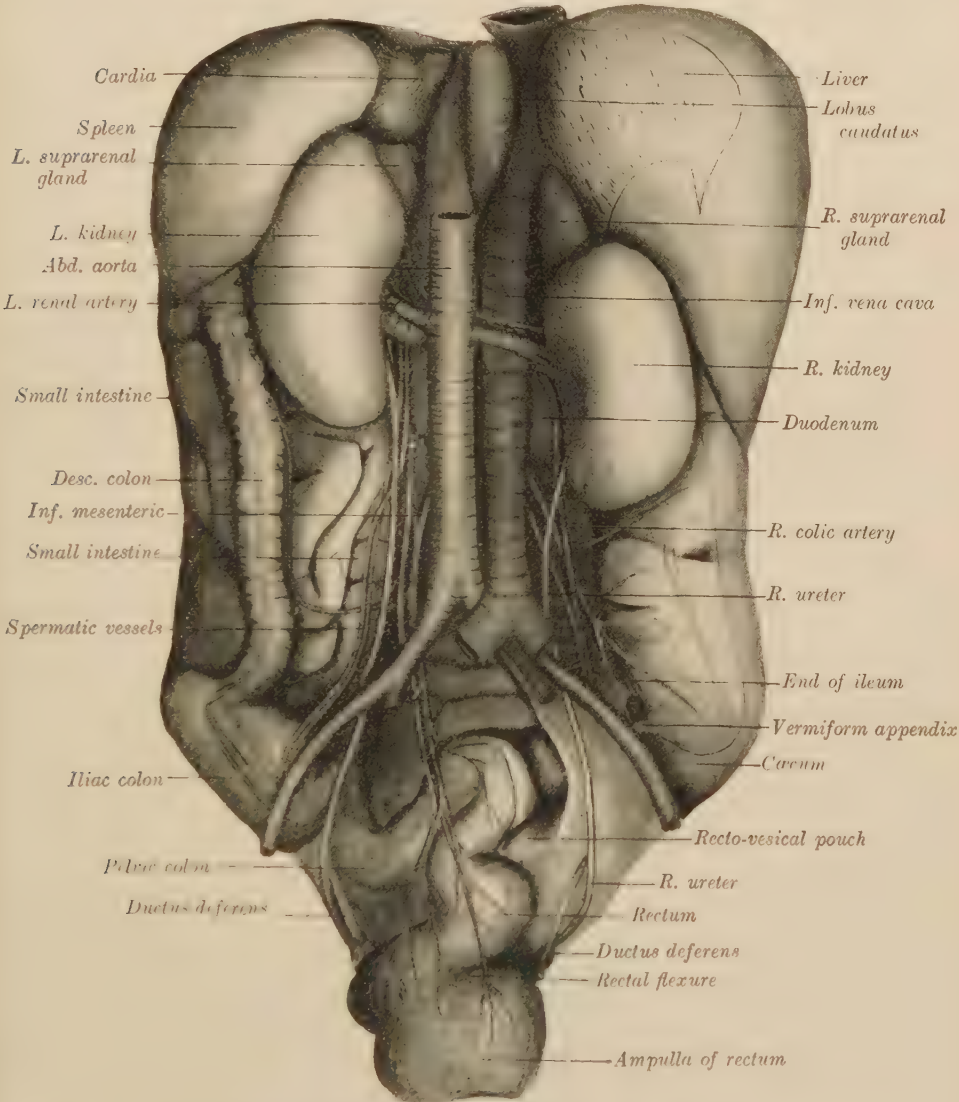


FIG. 74.—THE ABDOMINO-PELVIC VISCERA OF A MAN AGED FIFTY-ONE YEARS, VIEWED FROM BEHIND. One-third natural size. (J. Symington.)

groove, the abdominal mass presents a well-marked eminence, which is convex from side to side, but diminishes in breadth and prominence from above downwards.

The average capacity of the abdomino-pelvic cavity[1] in three adult males was a little over 6,000 c.c., and about two-thirds of this space was situated above the level of the umbilicus. The most capacious part of the abdomen is opposite the

[1] J. Symington, 'The Abdomino-pelvic Cavity,' *Jour. Anat. and Phys.*, vol. xvii., October 1912.

lowest thoracic and upper two lumbar vertebræ. A diminution in the capacity of the abdominal contents of an individual is associated with a retraction of the anterior abdominal wall, and an increase with a protrusion. This wall yields most readily in the region of the umbilicus, which is, therefore, the seat of

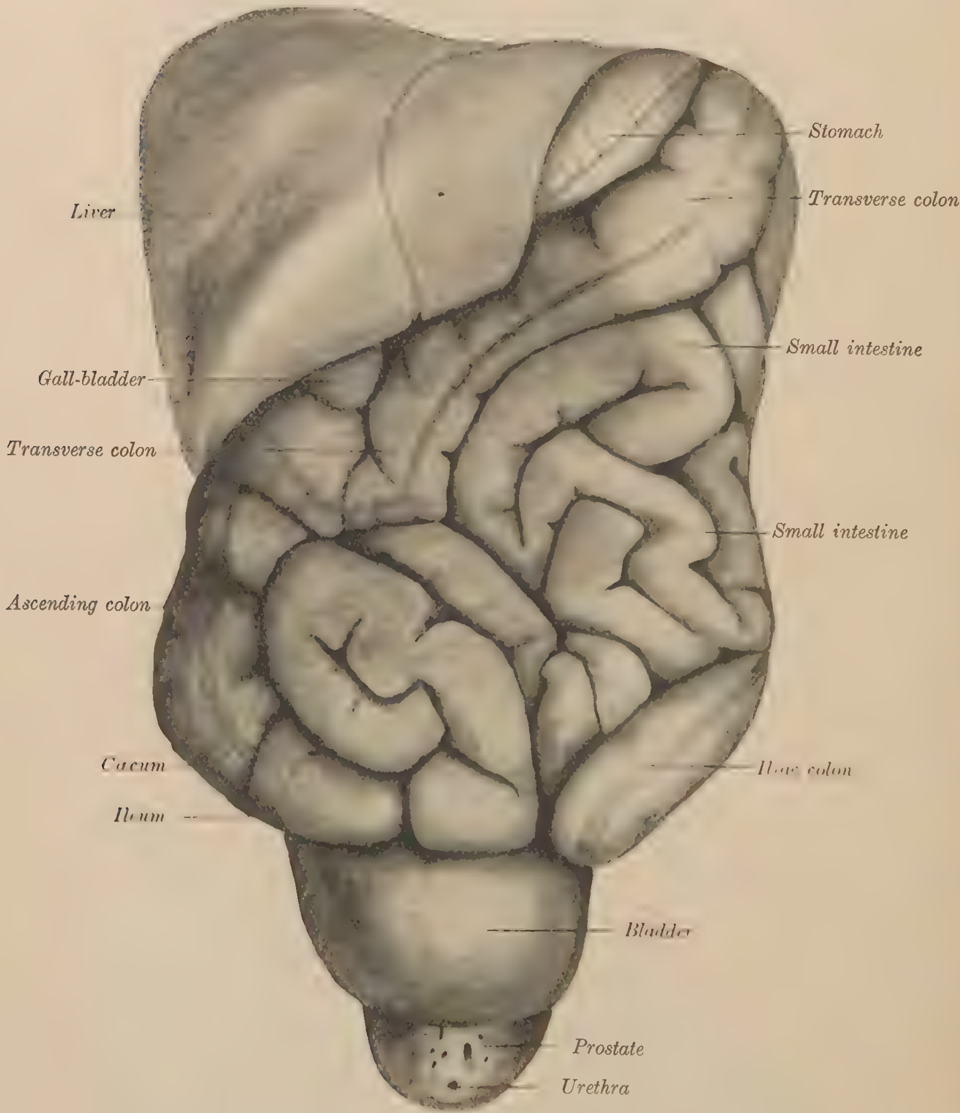


Fig. 75.—The abdomino-pelvic viscera of a man, aged fifty-one years, viewed from the front. One-third natural size. (J. Symington.)

the maximum retraction or protrusion. If the protrusion is marked and associated with a lax condition of the abdominal wall, the anterior wall hangs down, forming the so-called pendulous belly. Additional space for the abdominal contents may also be obtained by an elevation of the lower part of the thoracic wall and the diaphragm, and a bulging outwards of the lateral walls.

PERITONÆUM.

The peritoneum or serous membrane of the abdominal cavity is by far the most extensive and complicated of the serous membranes. It is derived from the intra-embryonic cœlom—a cavity formed by the splitting of the ventral laminæ of the mesoblast into the somato-pleure and splanchno-pleure layers. By the fusion of the somato-pleure layers on the ventral aspect of the body wall, the cavity becomes shut off from the extra-embryonic cœlom. In the male, it forms a closed sac ; but in the female each of the two oviducts (tubæ uterinæ) communicates with the cavity by a small aperture (ostium abdominale). The inner surface of the sac becomes lined by a layer of flat cells, called endothelium, which makes it very smooth. The cavity contains a small quantity of fluid, which serves to lubricate its interior, and thus to facilitate the movements of the opposing surfaces of the membrane upon one another. Outside the endothelium, the peritoneal wall is composed of connective tissue in which its blood-vessels, &c., lie, and which connects it with adjacent structures. Various organs are developed in the tissues between the abdominal wall and the lining membrane of the peritoneal cavity, mainly on the dorsal aspect. Where such organs exist, they must separate the peritoneum from the abdominal wall and become covered by it (visceral peritoneum), while, in other situations, the peritoneum remains closely related to the abdominal wall (parietal peritoneum). An organ may grow away from the abdominal wall towards the peritoneal cavity, and expand more rapidly than the tissues uniting it with the abdominal wall, so that a fold is formed, having a more or less linear attachment to the abdominal wall and to the organ. This fold consists of two layers of peritoneum, with blood-vessels, &c., embedded in connective-tissue between them. Such a structure, uniting the alimentary canal to the posterior abdominal wall, forms its mesentery. As the canal becomes differentiated, the mesentery is given names indicating the different parts of the canal to which it is attached—such as meso-gastrium, meso-appendix, and meso-colon ; while the term mesentery (*mesenterium commune*) is retained for the fold connected with the jejuno-ileum of the small intestine. Folds uniting abdominal or pelvic organs, other than the alimentary canal, with the abdominal or pelvic walls are commonly termed ligaments, hence the ligaments of the liver, bladder, uterus, &c.

The stomach and the adjacent portion of the duodenum are united in the embryo by peritoneum with the ventral as well as the dorsal portion of the abdominal wall, so that there is a ventral in addition to a dorsal meso-gastrium. In the ventral meso-gastrium the liver is developed, and in the dorsal the pancreas and spleen. The part of the ventral meso-gastrium which remains to unite the stomach and liver, and of the dorsal meso-gastrium to connect the stomach and the spleen, are called the small omentum and the gastro-splenic omentum, respectively. A fold which joins the stomach and transverse colon with one another is called the great omentum. As all the three omenta are connected with the stomach, an omentum is sometimes defined as a fold of the peritoneum uniting the stomach with some other abdominal organ. In the Basle 'Nomina anatomica,' generally known as the 'B.N.A.,' only two omenta are recognised: namely—the small and great ; and the gastro-splenic omentum is called *ligamentum gastro-lienale*. The term *plica* is used in the 'B.N.A.' for a fold passing from the stomach to the pancreas (*plica gastro-pancreatica*), and *ligament* for one going from the diaphragm to the colon (*ligamentum phrenicocolicum*). Further, it speaks of a mesorchium or mesentery of the testicle ; while the broad ligament of the uterus is divided into the mesometrium, mesosalpinx, and mesovarium, or mesenteries of the uterus, uterine tube, and ovary.

Owing to the different abdominal organs growing at very unequal rates, their mutual position becomes altered from the primitive one; again, certain parts of the peritoneal cavity may become obliterated by fusion of the opposing surfaces, or the cavity may extend so as to separate organs from one another or from the abdominal wall, which were formerly in direct contact. In consequence of such changes, the peritoneal cavity becomes very complicated; but with the exception of the serous covering of the testicles, the peritoneum normally remains a single continuous membrane. In descriptive anatomy, the peritoneal cavity is often described as forming two sacs—the greater and the lesser; but these are continuous with one another by a constricted aperture.

The relations of the peritoneum to each abdominal organ will be given with its descriptive anatomy, and a further general account of the peritoneum will be deferred until all the abdominal viscera have been described.

DELIMITATION OF THE ABDOMEN.

On account of the large size of the abdomen and the numerous organs contained within it, anatomists have generally recognised the necessity—in topographical descriptions and clinical observations—of its subdivision; but they are by no means agreed as to the plan by which this can be best attained.[1]

The surface of the abdomen for practical purposes may be regarded as bilaterally symmetrical, and the anterior and posterior median lines can readily be determined, so that a division into right and left halves presents no difficulty. The umbilicus forms a well-defined landmark on the front of the abdomen, and it is often at the same level as a transverse line on the back, uniting the highest parts of the two iliac crests. By dividing the abdomen horizontally at the umbilicus, and combining this division with that through the median sagittal plane, we have four regions mapped out. While this method presents the obvious advantage of simplicity, the four areas are too large to be of practical use in defining the position of many of the abdominal organs. Further, it has been shown [2] that the range of variation of the length, from the supra-sternal notch to the umbilicus, as compared with the length from the notch to the pubic symphysis, is from slightly over three-fourths to less than two-thirds. As the average distance from the supra-sternal notch to the pubic symphysis is about 52 cm., the range of variation is equal to 8 cm., or more than the depth of two lumbar vertebræ. Addison, in forty adults, found that the maximum variation in relation to the highest part of the iliac crests was 5·5 cm.

A method, which has the sanction of antiquity, and which is generally adopted in this country, is that of mapping out nine regions by two horizontal and two lateral sagittal planes (fig. 76). Since the three median areas admit of a division into right and left portions, this plan offers a sufficiently minute subdivision for all practical purposes. The general principle determining the selection of the horizontal

1 (*a*) William Anderson, 'A Plea for Uniformity in the Delimitation of the Regions of the Abdomen,' *Jour. Anat. and Phys.*, vol. xxxvi., 1892.
(*b*) D. J. Cunningham, 'Delimitation of Regions of the Abdomen,' *Jour. Anat. and Phys.*, vol. xxvii., 1893.
(*c*) A. Thomson, 'The Topographical Anatomy of the Abdomen,' *Brit. Medical Jour.*, vol. ii., 1895.
(*d*) F. Merkel, 'Topographische Anatomie. Bauch,' *Ergebnisse der Anatomie*, Bd. v., 1895.
(*e*) C. Addison, 'On the Topographical Anatomy of Abdominal Viscera in Man,' *Jour. Anat. and Phys.*, vols. xxxiii., July 1899; xxxiv., July 1900; and xxxv., April 1901.

2 Majorie M. Johnson, 'A Study in Surface Anatomy, with Special Reference to the Position of the Umbilicus,' *The Anatomical Record*, vol. v., 1911.

planes is that the upper one should correspond to the lowest limit of the thoracic wall, and the lower to the highest part of the pelvic wall. Certain difficulties attend a too rigid application of this principle: the main one being that the zone between the two horizontal lines is too narrow, or may even disappear, owing to the lower ribs reaching as far down as the level of the iliac crests. Cunningham proposed certain modifications of these principles. He made the upper or subcostal plane at the level of the lowest part of the tenth costal cartilages, and the lower or intertubercular plane opposite the prominent tubercle on the iliac crests, about 5 cm. from the anterior superior iliac spines. Three horizontal zones were thus marked on the abdomen: termed, from above downwards, costal, umbilical, and hypogastric. Not infrequently, the eleventh rib forms the lowest part of the thoracic wall; but it is variable in length, and not so easily seen as the lowest part of the tenth costal cartilages. The selection of the highest part of the iliac crests as the lower horizontal plane would have the advantage of including the whole of the two iliac fossæ in the hypogastric zone; but, as these crests sometimes reach a little higher than the umbilicus, the middle or umbilical zone might be entirely above the umbilicus. The intertubercular plane of Cunningham seems a reasonable compromise between the top of the iliac crests and the anterior superior iliac spines, and it corresponds to the highest part of the iliac crest visible from the front.

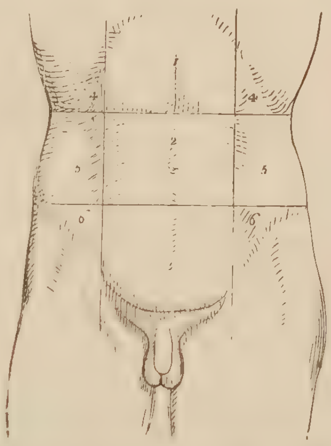


FIG. 76.—OUTLINE OF THE FRONT OF THE ABDOMEN SHOWING THE DIVISION INTO REGIONS. (Jones Quain.)

1, Epigastric region; 2, umbilical; 3, hypogastric; 4, 4, right and left hypochondriac; 5, 5, right and left lumbar; 6, 6, right and left iliac.

The two lateral lines are sometimes made by drawing a vertical line upwards from a point over the middle of the inguinal ligament; but the mid-point of a horizontal line uniting the anterior superior iliac spine and the median line is more easily ascertained. The mid-inguinal point is farther out than one midway between the anterior superior iliac spine and the median line; and in some individuals with a narrow waist, only a very small portion of the abdominal cavity lies lateral to a vertical line prolonged upwards from that point. The nine regions thus marked out are named in the costal zone, the right and left hypochondriac and epigastric; in the umbilical zone, the right and left lumbar and umbilical; and in the hypogastric zone, the right and left iliacs and the hypogastric.

The three zones are of unequal breadth. Cunningham found the average vertical extent in the middle line was 6 inches for the costal zone, 2·7 inches for the umbilical, and 5 inches for the hypogastric. He fixed the upper limit of the costal zone at the lower border of the body of the sternum, and the lower limit of the hypogastric at the upper border of the pubic symphysis. The fact that the umbilical zone is only about half the breadth of the other two and that, with the exception of the ascending and descending colon and the lower ends of the kidneys, its contents include the most movable parts of the alimentary canal—namely, the lower portion of the stomach, the transverse colon, and the convolutions of the jejuno-ileum—render it of but little use in mapping out the position of the abdominal organs. The epigastric, umbilical, and hypogastric divisions are much larger than their associated lateral areas; but this is not a serious objection, as each one is divisible into right and left portions.

The viscera, which are contained in the several regions, are shown in the following table, modified from one by G. D. Thane and R. J. Godlee :—

Epigastric region	The greater part or the whole of the left lobe, and part of the right lobe of the liver, with the gall-bladder, part of the stomach, including both orifices, the first and second parts of the duodenum, the duodeno-jejunal flexure, the pancreas, upper or inner end of the spleen, parts of the kidneys, and the suprarenal glands.
Hypochondriac, right ..	The greater part of the right lobe of the liver, the hepatic flexure of the colon, and part of the right kidney.
Hypochondriac, left ...	Part of the stomach, with the greater portion of the spleen and the tail of the pancreas, the splenic flexure of the colon, part of the left kidney, and sometimes a part of the left lobe of the liver.
Umbilical	The greater part of the transverse colon, the third part of the duodenum, some convolutions of the jejunum and ileum, with portions of the mesentery and great omentum, part of the right or sometimes of both kidneys, and the ureters.
Lumbar, right	The ascending colon, part of the right kidney, and sometimes part of the ileum.
Lumbar, left	The descending colon, part of the jejunum, and sometimes a small part of the left kidney.
Hypogastric	The convolutions of the ileum, the ureters, the bladder, and uterus in children; the upper part of the bladder and of the uterus in adults; the ovaries, and behind, the pelvic colon and upper part of the rectum.
Iliac, right	The cæcum with the vermiform appendix, and the termination of the ileum.
Iliac, left	The iliac colon, convolutions of the jejunum and ileum.

For all practical purposes, it is impossible to distinguish the contents of the hypogastric region above the oblique plane of the pelvic brim from those below that

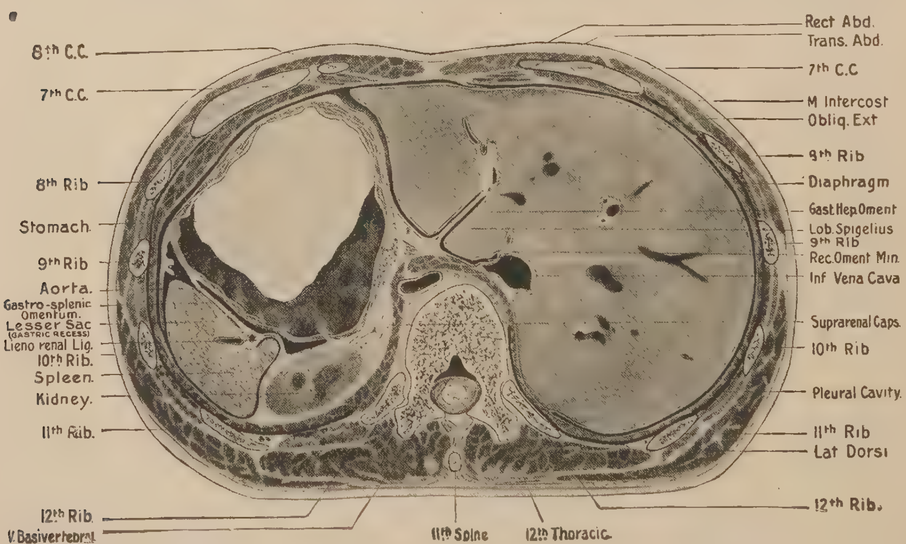


Fig. 77.—Horizontal section of trunk at the level of the body of the twelfth thoracic vertebra and upper surface of slab 2, on fig. 87. (P. T. Crymble.)

plane, and therefore those pelvic viscera that lie above the level of the upper border of the pubic symphysis are included in this region. The lower end of the bladder, the prostate, and seminal vesicles, the lower end of the uterus and the vagina, and the lower part of the rectum are situated posterior to the anterior wall of the bony pelvis.

C. Addison has devised a method of dividing both the thorax and abdomen into regions, which is independent of the variability in depth of the lower thoracic wall, and places the horizontal demarcation planes at equal distances from one another. A median line is drawn from the supra-sternal notch to the top of the pubic symphysis,

FIG. 78.—HORIZONTAL SECTION OF TRUNK AT THE LEVEL OF THE BODY OF THE FIRST LUMBAR VERTEBRA AND UPPER SURFACE OF SLAB 3 ON FIG. 87.—(P. T. Crymble.)

FIG. 79.—HORIZONTAL SECTION OF TRUNK AT THE LEVEL OF THE BODY OF THE SECOND LUMBAR VERTEBRA AND UPPER SURFACE OF SLAB 4 ON FIG. 87. (P. T. Crymble.)

and across this three transverse lines: one at the middle of its length—*the upper transverse abdominal line*; another midway between this line and the pubic symphysis —*the lower transverse abdominal line*; and the third across the thorax midway between the upper transverse abdominal line, and the supra-sternal notch—*the transverse thoracic line.* Addison found the average length of the median line, in forty adult subjects, was 52 cm.—this gives a vertical extent of 13 cm. for each

horizontal zone. These horizontal lines are the anterior edges of horizontal planes passing through the trunk.

The lower transverse abdominal line closely corresponds to the level of the intertubercular line of Cunningham, and the hypogastric zone below it is practically identical with that of Cunningham's. The upper transverse abdominal line is higher than Cunningham's subcostal line, and divides the vertebral column, as a

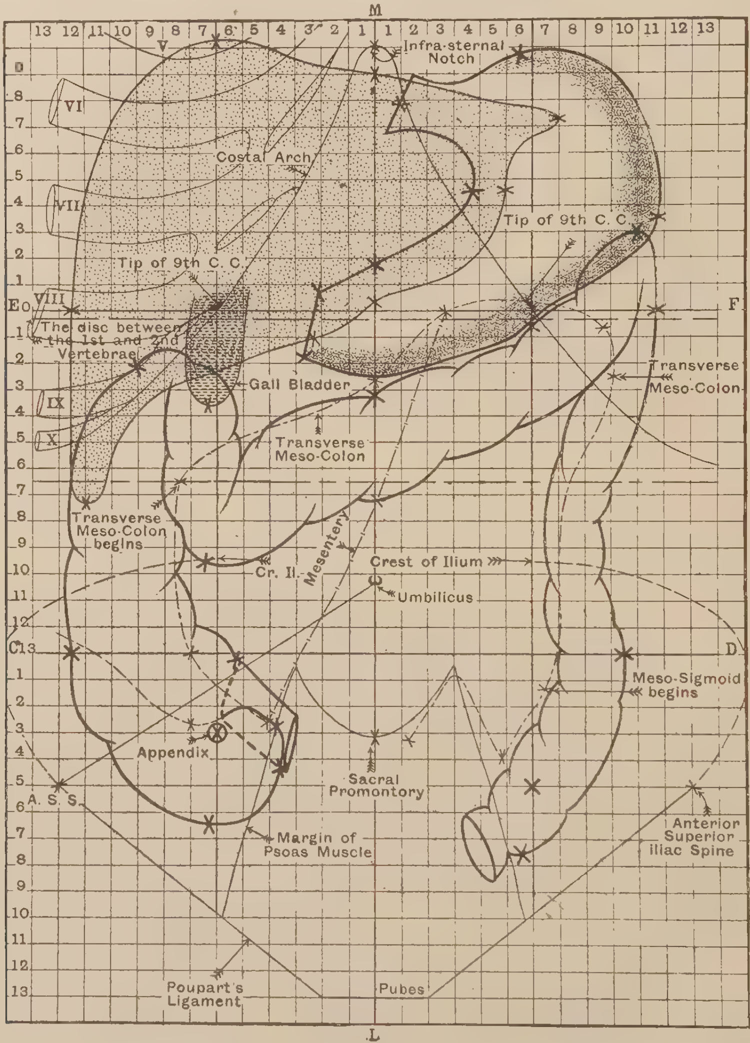


FIG. 80.

FIGS. 80 AND 81.—DIAGRAMS TO ILLUSTRATE ADDISON'S METHOD OF DELIMITATION OF THE REGIONS OF THE ABDOMEN AND THE AVERAGE POSITION OF THE PRINCIPAL ABDOMINAL VISCERA. (C. Addison.)

EF, upper transverse abdominal line; CD, lower transverse abdominal line; M, median line; right and left lateral lines pass downwards from between numbers 6 and 7 at top of diagram. In addition

rule, at the disk between the first and second lumbar vertebræ and the anterior thoracic wall near the tip of the ninth costal cartilage. The space between the upper and lower transverse abdominal lines may be termed the umbilical zone, it differs from the umbilical zone of Cunningham in its greater breadth owing to the higher position of its upper boundary.

The subcostal zone, situated between the upper transverse abdominal and the transverse thoracic lines, includes portions of both the thoracic and abdominal cavities. The larger part belongs to the abdomen, as the vault of the diaphragm crosses the trunk a little above the junction of the middle and upper thirds of the subcostal zone.

The three vertical lines—right and left lateral and median—are similar to

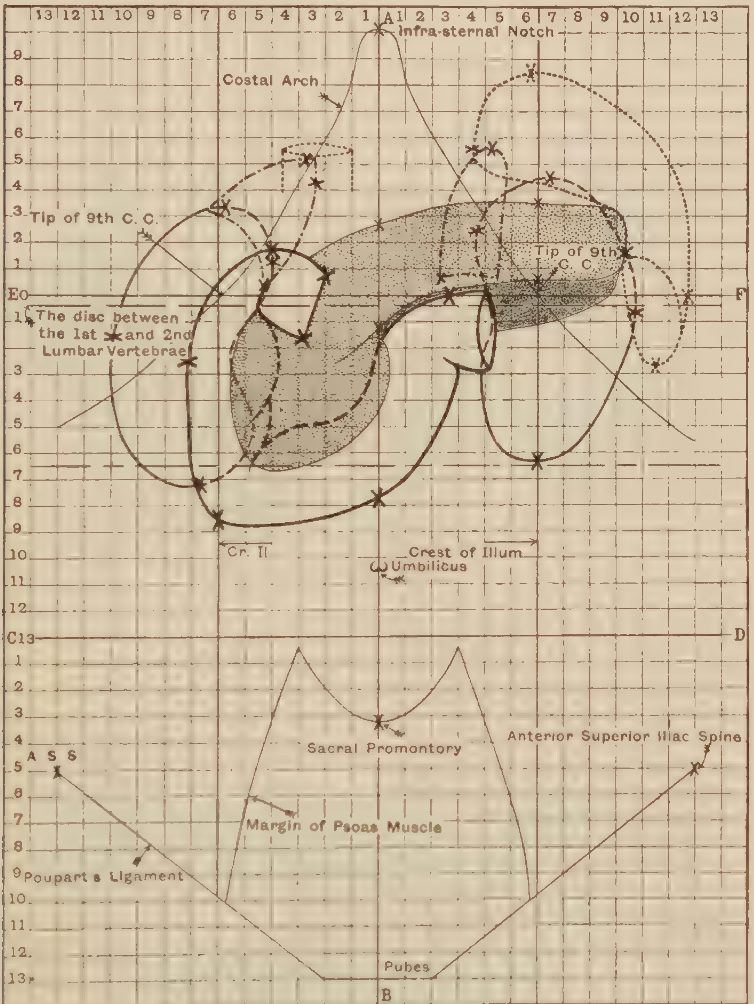


FIG. 81.

to these lines, the whole area of the abdomen was subdivided into square centimetres reduced in figure to 0·36 natural size. The position of the more superficial organs are given in fig. 80, and the deeper in fig. 81.

those already described in connexion with the account of Cunningham's divisions of the abdomen, and the same names may be applied to the four regions of each zone.

The average position of the principal abdominal organs in relation to Addison's lines and areas is shown in figs. 80 and 81. From this it will be seen that a section through the upper transverse abdominal plane (E. F. in figs. 80 and 81) would

divide the lower part of the stomach, the pylorus, the upper part of the duodenum, left end of transverse colon, the splenic flexure of the colon, the liver, the gall-bladder, the pancreas, the spleen, and both kidneys. As Addison found, in a considerable majority of the forty cases he examined, that the pylorus was either in this plane or close to it, he proposed to name it the transpyloric plane.

A table is appended, showing the contents of the different regions of the subcostal and umbilical zones of Addison. Since the hypogastric zone is practically identical with that of Cunningham's (see p. 75), the list of viscera contained in it is not repeated here.

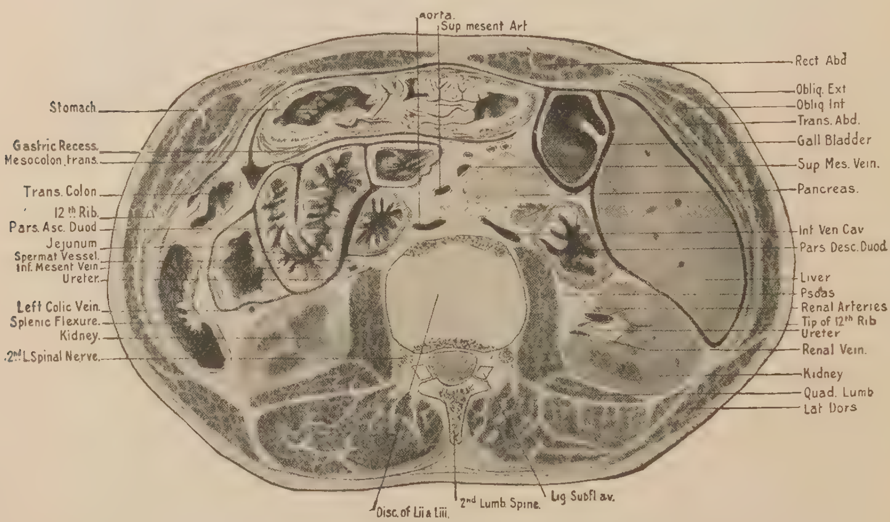


Fig. 82.—Horizontal section of trunk at the level of the disk between the bodies of the second and third lumbar vertebræ and at the surface of slab 5 on fig. 87. (P. T. Crymble.)

Table giving the average position of the abdominal organs in relation to Addison's areas :—

Subcostal Zone.

Epigastric, right	Small part of left lobe of liver, part of the right lobe of the liver, part of gall-blader, upper and inner part of right kidney, right suprarenal gland, upper part of pylorus, and sometimes adjacent portion of stomach, neck and upper part of head of pancreas, first and commencement of second part of duodenum.
Epigastric, left	Greater part of left lobe of liver, cardiac orifice, and adjacent portion of stomach ; body of pancreas, left suprarenal gland, upper part of spleen, upper and median part of left kidney.
Hypochondriac, right...	Part of right lobe of liver, part of gall-bladder, lateral and upper part of right kidney.
Hypochondriac, left	Left part of fundus and body of stomach, left extremity of left lobe of liver, greater part of the spleen, tail of pancreas, splenic flexure of colon, lateral and upper part of left kidney.

Umbilical Zone.

Umbilical, right	Lower part of pylorus and adjacent portion of stomach, part of right lobe of liver, part of gall-bladder, second part of duodenum, part of transverse colon, part of jejuno-ileum, head of pancreas, median and lower part of right kidney, right ureter.
Umbilical, left	Lower part of stomach, part of transverse colon, median and lower part of left kidney, left ureter, terminal portion of duodenum and part of jejunum.

Lumbar, right	Lower part of right lobe of liver, part of gall-bladder, lower and outer part of right kidney, outer part of second portion of duodenum, ascending colon, hepatic flexure and part of transverse colon.
Lumbar, left	Lower end of spleen, outer and lower part of left kidney, part of transverse colon, lower part of descending colon and upper part of iliac colon, jejunum.

The position and relations of the abdomino-pelvic organs and the structure of the abdominal wall are illustrated in a series of horizontal sections of a man

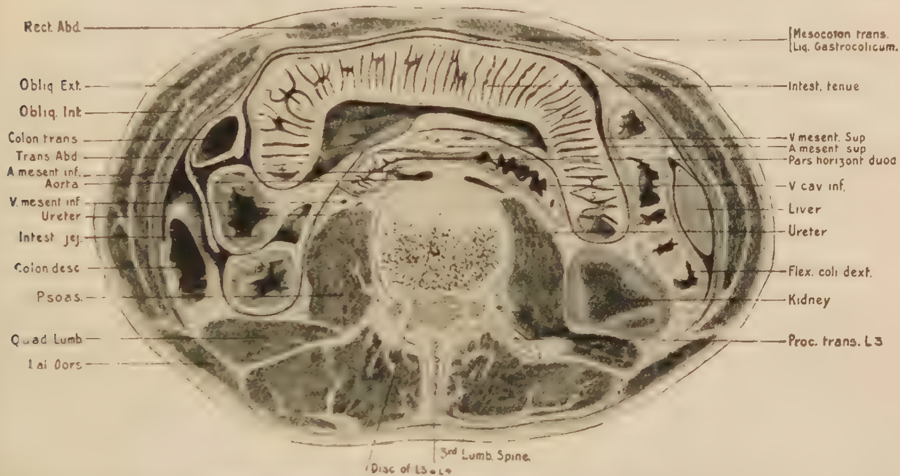


FIG. 83.—HORIZONTAL SECTION OF TRUNK AT THE LEVEL OF THE DISK BETWEEN THE THIRD AND FOURTH LUMBAR VERTEBRÆ AND THE UPPER SURFACE OF SLAB 6, ON FIG. 87. (P. T. Crymble.)

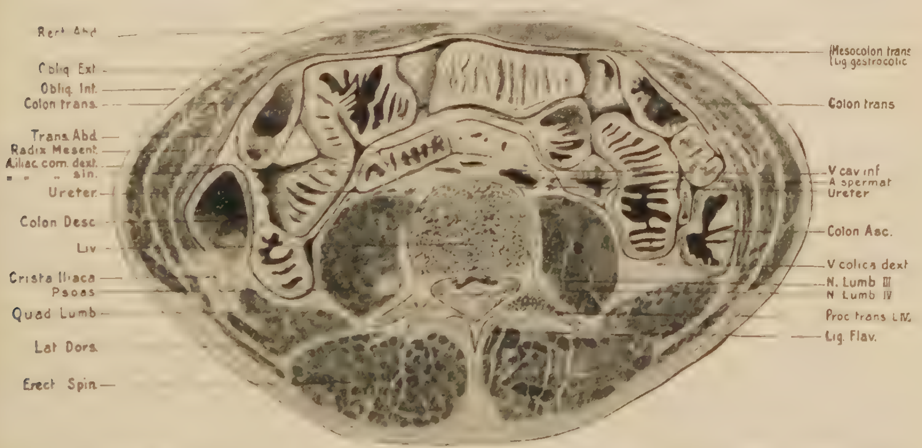


FIG. 84.—HORIZONTAL SECTION OF TRUNK AT THE LEVEL OF THE FOURTH LUMBAR VERTEBRA AND THE UPPER SURFACE OF SLAB 7, ON FIG. 87. This section is just above the umbilicus. (P. T. Crymble.)

aged fifty (see figs. 77 to 86), and the levels of these sections in relation to the skeleton are shown in fig. 87. All these figures are one-third natural size.

VENTRICULUS.

The stomach (*ventriculus* or *gaster*) is a dilated portion of the alimentary canal, situated between the termination of the œsophagus and the commencement of the small intestine. It forms a somewhat cylindrical tube bent like the capital letter J (fig. 88). The upper blind extremity is known as the fundus. From this the

larger part of the stomach passes downwards, forming the body or, with the fundus, the cardiac portion, and then, turning upwards and to the right, the pyloric part of the stomach. The fundus lies farther back than the lower end, and, viewed from the left side, the stomach is seen to slope obliquely downwards and forwards, while the axis of the main stem, as seen from the front, may be vertical, but frequently

FIG. 85.—HORIZONTAL SECTION OF TRUNK AT THE LEVEL OF THE DISK BETWEEN THE FIFTH LUMBAR AND FIRST SACRAL VERTEBRÆ AND THE UPPER SURFACE OF SLAB 9, ON FIG. 87. (P. T. Crymble.)

inclines somewhat to the right as it descends. Of its two openings, the one, by which food enters from the œsophagus, is situated to the right of the fundus, and is named the *cardiac orifice*; the other, by which it passes into the duodenum, and which is placed on a lower level and more forwards and to the right, is the *pyloric orifice*. The stomach has two surfaces, called anterior and posterior; and two borders, termed the great and small (greater and lesser) curvatures (figs. 88, 91).

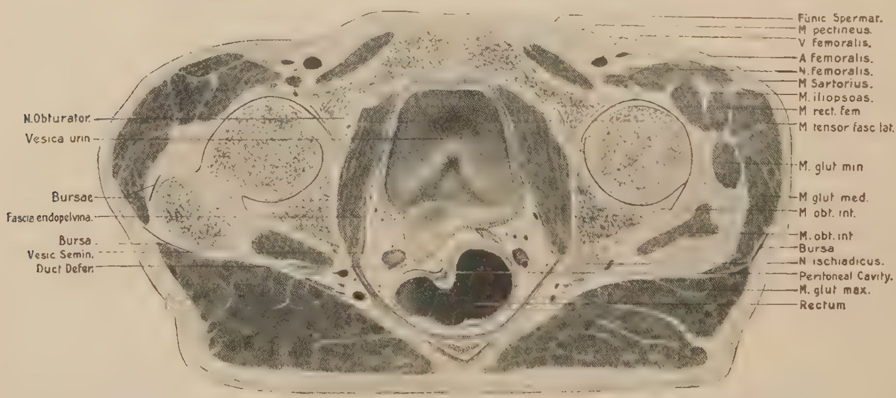


FIG. 86.—HORIZONTAL SECTION OF TRUNK AT THE LEVEL OF THE PUBIC SYMPHYSIS AND THE UPPER PART OF THE COCCYX. The section is the upper surface of slab 13, on fig. 87. (P. T. Crymble.)

Examination by X-rays and in the cadaver.—Our knowledge of the form, position, and movements of the stomach has been rendered much more exact by the examination of this organ in the living body after the administration of food containing bismuth—a method introduced by Rieder.[1] Compounds of bismuth being opaque to the X-rays, a shadow of the stomach contents after a meal of this kind can be thrown upon a photographic plate or a fluorescent screen; or by a

[1] 'Radiologische Untersuchung des Magens und Darmes beim lebenden Menschen,' *München Med. Wochensch.*, 1904, No. 35.

series of skiagrams, taken at regular intervals, a representation of the movements of the stomach during a definite period can be obtained. Such a series constitutes a Roentgen-kinematograph.

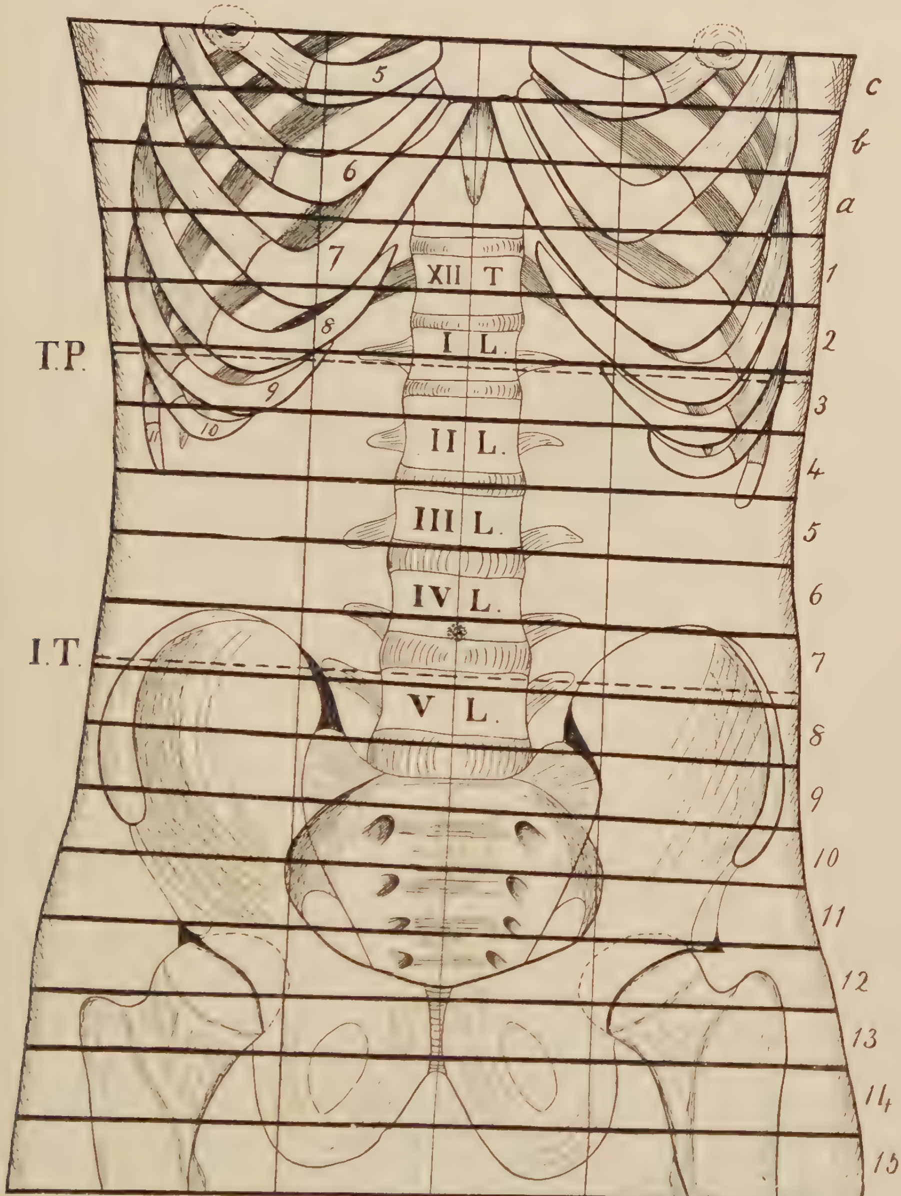
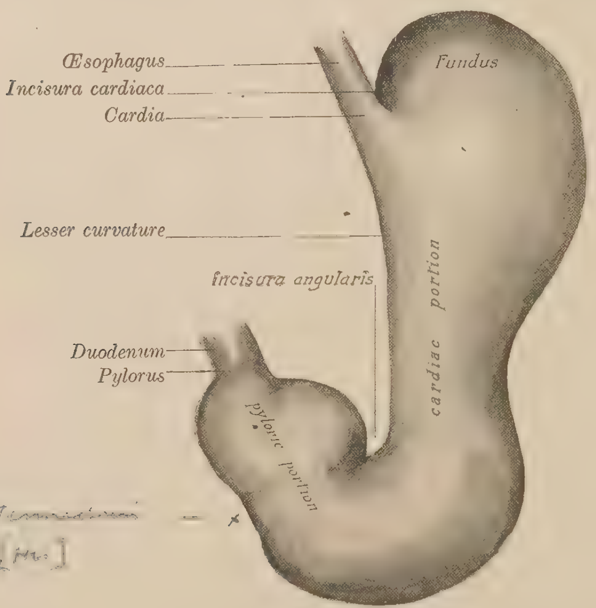


FIG. 87.—RECONSTRUCTION OF THE SKELETON OF A MAN, AGED FIFTY, WHOSE TRUNK WAS DIVIDED BY A SERIES OF HORIZONTAL SECTIONS INTO SLABS, EACH ABOUT 2·5 CM. THICK. One-third natural size. (J. Symington.)

The slabs are marked from above downwards, *c*, *b*, *a*, and 1 to 15. T.P., transpyloric or upper transverse abdominal line; I.T., intertubercular or lower transverse abdominal line. The three vertical lines on figure are the median and the right and left lateral.

The person to be examined is given a meal of about 400 grms., which is sufficient to fill the stomach. The meal consists of 350 grms. of porridge or other soft food mixed with 50 grms. of carbonate or oxychloride of bismuth.

In the standing position, the first bolus which enters the stomach can be seen, from the dark shadow on the screen, to lie first just below a clear area at the fundus and then to descend slowly to the lower or caudal pole. The succeeding boli pass down rather quicker, and when all the meal is taken the whole stomach is occupied



Sulcus intermedius – x
[His]

FIG. 88.—VIEW OF THE STOMACH FROM THE FRONT. One-third natural size. (J. Symington.)

by food, except the upper pole, where a quantity of gas has accumulated. The stomach does not act as a flaccid bag, allowing all the food to sink to the lowest part of the stomach, but is contracted on its contents, and maintains a cylindrical

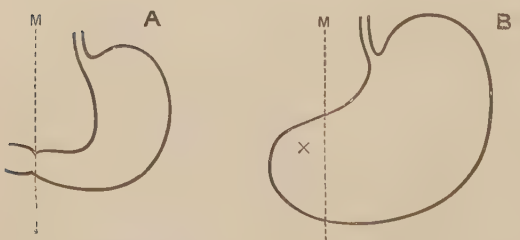


FIG. 89.—DIAGRAMMATIC OUTLINE OF THE EMPTY (A) AND DISTENDED (B) STOMACH SEEN FROM THE FRONT. (J. Symington.)

M, dotted line, represents the median plane. The × indicates position on back of organ of pyloric orifice.

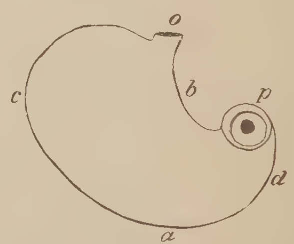


FIG 90.—DIAGRAMMATIC OUTLINE OF A MODERATELY DISTENDED STOMACH, AS SEEN FROM BEHIND. One-fourth natural size. (His.)

a, greater curvature; *b*, lesser curvature; *c*, fundus; *d*, antrum pyloricum; *o*, cardia; *p*, pylorus.

form. From observations on a large number of healthy persons, Groedel[1] found the average height of the stomach from the fundus to the caudal pole to be 20 cm. in males and 22 cm. in females, and the height of the pylorus above the caudal

[1] 'Atlas und Grundriss der Röntgendiagnostik in der inneren Medizin,' *München*, 1909.

pole 8·5 cm. in males and 8 cm. in females, while the greatest breadth of the stomach was 9·5 cm. in both sexes, the last-mentioned measurement being at the bend of the tube and therefore about double the straight portion of the tube. When a double meal (800 grms.) is taken, the length of the stomach remains practically the same, but its breadth is increased.

A normal stomach containing a moderate meal reaches, when the person is standing, somewhat below the umbilicus (see fig. 91). By voluntary contraction of the muscles of the anterior abdominal wall, or by pressure applied over the umbilical region of the abdomen, the lower limit of the stomach can be raised from

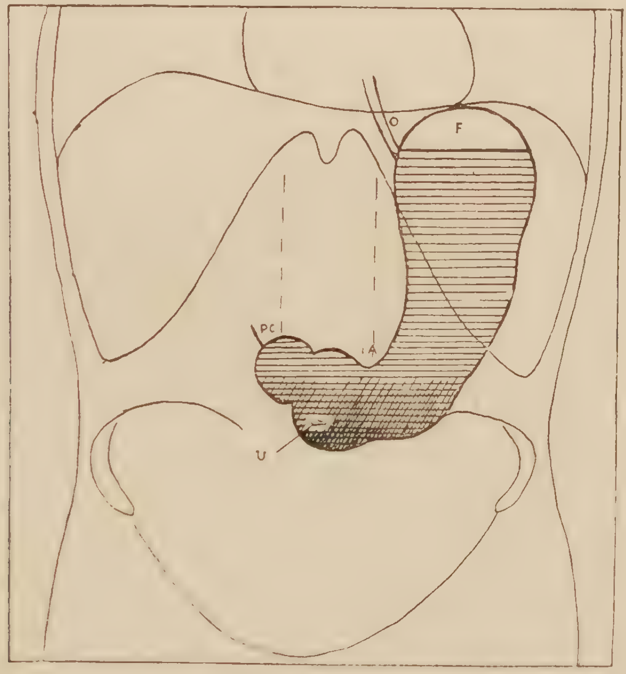


FIG. 91.—SHAPE AND POSITION OF STOMACH DURING LIFE, MODERATELY DISTENDED WITH A BISMUTH MEAL. (A. F. Hertz.)

O, œsophagus; F, fundus containing gas; U, umbilicus.

5 cm. to 13 cm. (Hertz), but returns to its former position when the muscles relax or the pressure is removed. An elevation of the lower part of the stomach also occurs when the person assumes the recumbent position.

Although the position of the stomach in the cadaver sometimes closely resembles that observed during life, yet, as a rule, its lower border is at a distinctly higher level, and the entire organ is often found with its anterior and posterior surfaces looking to a considerable extent upwards and downwards, so that some anatomists have described the normal position of the stomach as horizontal. C. Addison[1] found the average level of the lowest part of the great curvature of the stomach in the cadaver to be about 7·5 cm. above the umbilicus (see fig. 80), and these results are confirmed by the series of reconstructions made by P. Porter.[2] Groedel,[3] and other radiographers, agree that, after a bismuth meal and with the patient standing,

[1] 'On the Topographical Anatomy of Abdominal Viscera in Man,' *Jour. Anat. and Phys.*, vol. xxxiii., July 1899.

[2] See 'Topography of Organs,' in Eycleshymer and Schoemaker's *Cross-section Anatomy*, 1911.

[3] 'Atlas und Grundriss der Röntgendiagnostik in der inneren Medizin,' *München*, 1909.

the stomach reaches a little below the umbilicus. The lower end of the stomach (caudal pole) rises when the recumbent posture is assumed, and it is often found higher still in the cadaver. This elevation of the caudal pole is not associated with any marked rise in the level of the pylorus. Addison figures the pylorus about 2 cm. above the caudal pole in the cadaver, and Groedel gives the distance in the living erect patient as 8 cm. The higher level of the lower part of the stomach in the cadaver is partly due to the dissection being made in the horizontal position, for, as already mentioned, in the living body a marked rise occurs when the patient lies down. Further, after death, the stomach usually contains little or no food, and its lower part is frequently contracted, and as, during life, the expanding stomach

FIG. 92.—HORIZONTAL SECTION OF THE ABDOMEN OF A BOY AGED SIX YEARS, AT THE LEVEL OF THE CARDIAC ORIFICE. Natural size. (J. Symington.)

a, disk between the eleventh and twelfth thoracic vertebræ; *b*, diaphragm; *c*, aorta; *d*, cardiac orifice: behind this the stomach is seen to be in direct contact with the diaphragm.

meets with little resistance from the subjacent intestine, it must naturally be depressed by the accumulation of food. In the cadaver, the diaphragm is in a state of expiration, and the stomach will occupy a correspondingly high position.

By X-rays not only can the general position of a stomach containing a bismuth meal be demonstrated, but the action of the muscular coat and its influence upon the form of the cavity can be shown by changes in the shape of the shadow.[1] The fundus of the stomach is not subject to peristaltic movement. It serves as a temporary reservoir for the food, and always contains a quantity of gas. Peristaltic contractions begin below the cardiac orifice, and the constrictions in the cardiac portion of the stomach are better marked on the greater than on the lesser curvature. Towards the pylorus the peristalsis is more energetic, and the constrictions tend to become deeper and especially marked along the lesser curvature where this border turns to the right. A contraction-ring may form in the pyloric part of the stomach and nearly cut off the contents of a small portion, near the pylorus, from the rest of the stomach. As this contraction-ring passes towards the pylorus, another one is being formed behind it. It is probable that the contraction of the pyloric part of the stomach forces most of the contents back again into the main

[1] See Kaestle, Rieder, and Rosenthal, 'The Bio-roentgenography of the Internal Organs,' *Arch. of Roentgen Rays*, June 1910; and A. F. Hertz, 'The Motor Functions of the Stomach,' *Quarterly Journal of Medicine*, July 1910.

portion of the stomach, and only a small part into the duodenum; otherwise, the stomach would be emptied much quicker than is really the case, since several contraction-waves may occur in one minute.

After death, the stomach may be found firmly contracted—except at the fundus—so as to form a narrow intestinal tube, or it may present constrictions with intermediate dilatations, and the constrictions may be circular, or limited mainly to the neighbourhood of one of the curvatures. These constrictions are probably due to a contraction-wave, which was arrested at some part of its course, since the position at which they are found is very inconstant. Authorities are by no means agreed as to the number, position, and functional significance of the parts into which the stomach may be divided. F. T. Lewis [1] has recently drawn up the following table of the fundamental subdivisions of the stomach and the adjacent portions of the digestive tube :—

- Antrum cardiacum.
- Gaster.
  - Cardia.
  - Pars cardiaca gastri.
    - Fundus.
    - Corpus.
    - Canalis gastricus.
  - Pars pylorica gastri.
    - Vestibulum pyloricum.
    - Antrum pyloricum.
  - Pylorus.
- Antrum duodenale.

Antrum cardiacum is merely another name for the intra-abdominal portion of the œsophagus. It is often funnel-shaped, with its base towards the stomach.

Cardia. — The junction of the stomach and the œsophagus is called the *cardia*. Owing to its relations with the diaphragm, the cardia is the most fixed part of the stomach. It is situated at the level of the body of the tenth or eleventh thoracic vertebra, in front and to the left side of the aorta, and behind a notch in the posterior surface of the left lobe of the liver. It lies, on an average, about 10 cm. to 12 cm. posterior to the interval between the ensiform process and the inner end of the seventh left costal cartilage. It appears, from the researches of Braune and von Gubaroff,[2] that the cardiac orifice may have a valvular action independent of its muscular fibres. Thus, after dividing the thorax horizontally some distance above the diaphragm, and filling the stomach with fluid by injecting from the cut end of the œsophagus, they found that the gastric contents were retained, although the œsophagus was not ligatured. After piercing the diaphragm, the œsophagus

Fig. 93.—Section through pyloric part of stomach and commencement of duodenum, from a specimen hardened *in situ*. Natural size. (J. Symington.)

a, a, a, longitudinal folds of the mucous membrane in pyloric part of stomach; *b*, section of mucous membrane; *c*, circular muscular fibres of stomach: the longitudinal fibres are just visible to the naked eye as a narrow line external to the circular fibres; D, duodenum; P, pyloric orifice.

[1] 'The Form of the Stomach in Human Embryos, with Notes upon the Nomenclature of the Stomach. *The American Journal of Anatomy*, vol. xiii., 1912.

[2] 'Ueber den Verchluss des menschlichen Magens der Cardia,' *Arch. f. Anatomie*, 1886.

turns somewhat abruptly to the left side to open into the stomach, and it is probable that when the stomach is distended this bend is increased so as to obstruct the return of its contents into the œsophagus.

Pylorus.—This is the junction of the stomach and duodenum. Owing to the connexion of this end of the stomach with the liver by means of the thickened portion of the small omentum, containing the hepatic artery, portal vein, and bile-duct, its mobility is much less than various other parts of the stomach. Addison found that in twenty-four out of sixty subjects, the pylorus corresponded to, or was within 1 cm. of, the upper transverse abdominal plane (see fig. 80), and he consequently proposed to call this plane the *transpyloric*. Porter[1] gives the average level as opposite the first lumbar vertebra. It may be pushed down by

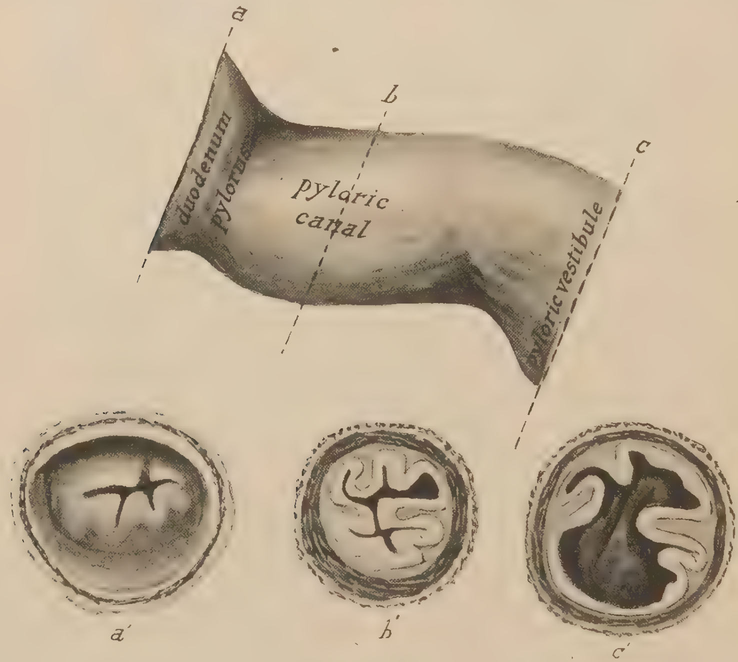


Fig. 94.—View of the pyloric portion of the stomach in a contracted condition. Natural size. (J. Symington.)

a, b, c, on upper drawing indicate the position of the three sections *a′, b′, c′*; *a′* shows the pyloric orifice seen from the duodenal side.

an enlarged liver, or displaced upwards by a distended transverse colon. In the cadaver, the pylorus is usually overlapped in front by the liver, which thus separates it from the abdominal wall; but during life, with the stomach full and the body in the erect position, the pylorus is probably a little below the liver. When the stomach is empty, the pylorus is in, or close to, the median plane, and 2 cm. to 3 cm. below the ensiform cartilage; but when the stomach is distended, it tends to move towards the right side, and the orifice which previously looked upwards and to the right is now turned backwards. The position of the pyloric orifice can be recognised by a slight constriction on the outer surface of the organ, and also by a thickening of the wall, which can readily be felt by taking it between the thumb and the forefinger. During operations, the position of the pylorus may often be recognised by the presence of a small vein crossing it transversely.

[1] Eycleshymer and Schoemaker's *Cross-section Anatomy*, 1911.

The cardiac portion (*pars cardiaca*) is the larger of the two main divisions of the stomach, and it consists of a fundus, body, and canalis gastricus. The *fundus* is a cul-de-sac, projecting upwards and backwards above the level of the cardia, and lies against the left vault of the diaphragm and the left lobe of the liver. The *corpus*, or body of the stomach, extends from the fundus to the caudal pole. The *canalis gastricus* is a narrow portion of the cavity of the stomach, reaching from the cardia to the incisura angularis, and bounded on the right side by the lesser curvature of the stomach, while on the left side it communicates with the body of the stomach. It is believed by some to serve as a channel, which facilitates the passages of liquids from the cardia directly to the pyloric part of the stomach. It is said to be well marked in the fetus.

The pyloric part (*pars pylorica*) is frequently described as divisible into the pyloric vestibule and the pyloric antrum. The pyloric vestibule is seldom distinctly marked off from the body of the stomach. The pyloric antrum is a small dilatation situated between the pyloric vestibule and the pylorus. Not infrequently it is found, after death, firmly contracted (see fig. 94), and it is then known as the pyloric canal.

Lewis found that, in a human embryo 10 mm. long, the stomach was already divided into an expanded cardiac and a tubular pyloric portion, and the incisura angularis was about midway between the cardia and the pylorus, and from this and other specimens, he concluded that the pyloric portion is relatively longer in the early stages of development than in the later ones.

A. Keith and Wood Jones, *Proc. Anat. Soc.*, November 1901, and in *Jour. Anat. and Phys.*, vol. xxxvi., state that the fundus of the stomach is developed as a local outgrowth, or diverticulum, from the cardiac end of the great curvature, and that it represents the first of the three divisions of the stomach of the primates, the other two being the body and the pyloric part. In Semnopithecus, the stomach is sharply differentiated into these three portions.

The portion of the stomach between the cardia and the pylorus is usually described as having two surfaces and two borders, although in an active state, it acquires a more or less cylindrical form.

Surfaces.—The *anterior surface*, which looks more or less upwards as well as forwards, is entirely covered by the peritoneum of the greater sac. It is in contact with the under-surface of the left lobe of the liver and the diaphragm, and frequently also with the quadrate lobe of the liver and the anterior abdominal wall below the costal margin. Occasionally, the transverse colon is found in front of the stomach.

The *posterior* surface is covered above by the greater sac, the peritoneum being continued from the anterior surface over the fundus on to the upper part of the posterior aspect. In the neighbourhood of the cardia, there is an area of the stomach of variable size, uncovered by peritoneum. When small, this area is in direct contact with the diaphragm (see fig. 92), and is bounded by the gastro-phrenic ligaments; but it may be so large as to reach outwards to the left kidney and suprarenal gland, and as far downwards as the pancreas, when the area becomes limited partly by gastro-renal and gastro-pancreatic folds. The pyloric part of the posterior surface of the stomach may be covered by the peritoneum of the lesser sac, but not infrequently it lies in direct contact with the pancreas. Sometimes the uncovered area extends along the lesser curvature, from the cardia to the pylorus, in which case the lesser sac is divided into two distinct portions—the bursa omenti majoris and bursa omenti minoris. The posterior aspect of the body of the stomach is lined by the peritoneum of the recessus lienalis of the bursa omenti majoris. (For further particulars regarding the relation of the posterior surface of the stomach to the peritoneum, see P. T. Crymble, 'Gastro-pancreatic Folds,' *Jour. Anat. and Phys.*, vol. xlvii.)

The structures which lie behind the stomach were described by the late Professor Birmingham[1] as forming the stomach-bed. They include a small part of the diaphragm, the gastric surface of the spleen, sometimes part of the suprarenal gland and the upper end of the kidney, the pancreas, and the transverse meso-colon. This peritoneal fold separates the lower part of the stomach from some of the convolutions of the jejunum (fig. 82).

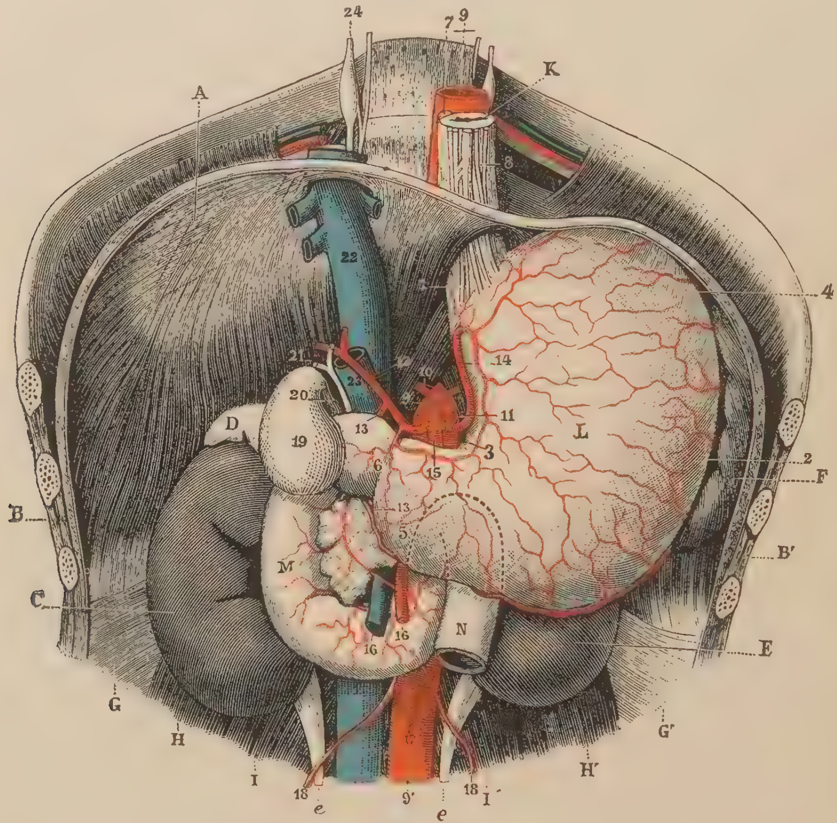


Fig. 95.—View of the stomach *in situ* after removal of the liver and the intestine (except the duodenum and commencement of jejunum). (Testut.)

A, diaphragm ; B, B′, thoracico-abdominal parietes ; C, right kidney with *e*, its ureter ; D, right suprarenal gland ; E, left kidney with *e*, its ureter ; F, spleen ; G, G′, aponeuroses of the transverse abdominal muscles ; H, right quadratus lumborum muscle ; H′, left ditto ; I, right psoas magnus and parvus muscles ; I′, left ditto ; K, œsophagus ; L, stomach ; M, duodenum ; N, jejunum ; the position of the duodeno-jejunal junction behind the stomach is indicated by dotted lines. 1, termination of œsophagus ; 2, great curvature of stomach ; 3, small curvature ; 4, fundus ; 5, antrum pylori ; 6, pyloric end ; 7, right vagus nerve ; 8, left ditto ; 9, thoracic aorta ; 9′, abdominal aorta ; 10, inferior phrenic artery ; 11, cœliac artery ; 12, hepatic artery ; 13, right gastro-epiploic ; 14, left gastric artery ; 15, splenic artery ; 16, 16′, superior mesenteric artery and vein ; 17, inferior mesenteric artery ; 18, spermatic arteries ; 19, gall-bladder ; 20, cystic duct ; 21, hepatic duct ; 22, inferior vena cava ; 23, portal vein ; 24, sympathetic cord.

Borders.—The borders of the stomach are termed the small and great curvatures. They give attachment to folds of peritoneum, between the layers of which blood-vessels and lymphatics reach the organ. The small curvature is readily recognised by its giving attachment to the *small omentum*. It passes from the cardia at first downwards and a little to the left, and then turns somewhat

[1] 'Some Points in the Anatomy of the Digestive System,' *Jour. Anat and Phys.*, vol. xxxv., October 1900.

abruptly upwards and to the right, to end at the upper border of the pylorus. This bend on the lesser curvature is known as the *incisura angularis.*[1] Between this notch and the pylorus, the lesser curvature often exhibits a depression, separating two prominences. The great curvature is about three times (Berry) as long as the small, and consists of an upper, a left, and a lower portion. At its commencement, it is separated from the cardia by a deep notch—the *incisura cardiaca*. From this

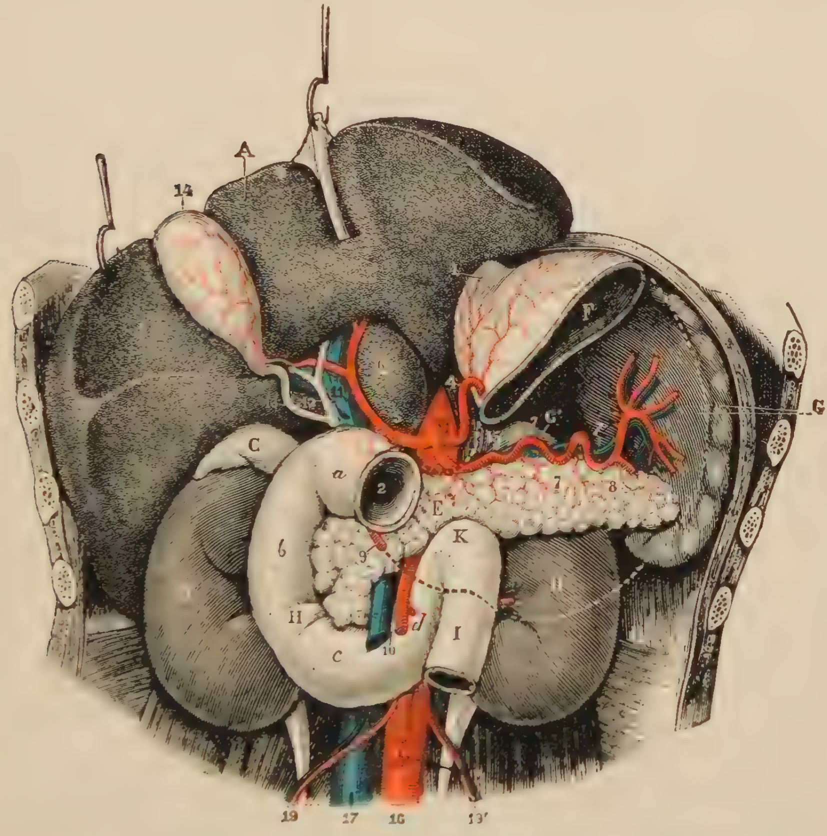


FIG. 96.—VIEW OF THE LIVER, DUODENUM, PANCREAS, SPLEEN, ETC. The greater part of the stomach has been removed to show its posterior relations; its position is indicated by a dotted outline. (Testut.)

A, inferior surface of liver; B, right kidney; C, C′, right and left suprarenal glands: D, left kidney; E, pancreas; F, upper part of stomach; G, spleen; H, duodenum with *a*, *b*, *c*, *d*, its four portions; I, jejunum; K, duodeno-jejunal junction; 1, lower end of œsophagus; 2, pyloric orifice; 3, cœliac artery; 4, left gastric artery; 5, hepatic artery; 6, lobus caudatus of liver; 7, 7′, splenic vessels; 8, left gastro-epiploic; 9, right gastro-epiploic; 10, superior mesenteric vessels; 11, portal vein; 12, hepatic duct; 13, cystic duct; 14, gall-bladder; 15, left crus of diaphragm, 16, aorta; 17, inferior vena cava; 18, inferior mesenteric vessels; 19, 19′, spermatic vessels.

notch, it will be found to pass to the left, forming an upwardly directed convexity, where it encircles the upper part of the fundus. On the left side of the fundus, it first passes nearly straight downwards, and then turns to the right to end at the pylorus. Its vertical portion gives attachment to the gastro-splenic ligament (*ligamentum gastrolienale*), and its lower to the great omentum. The transverse colon generally lies near the lower border of the stomach. Depressions on the

[1] His, 'Studien an geharteten Leichen ueber Form und Lagerung des menschlichen Magens,' *Arch. f. Anatomie*, 1903.

greater curvature are often seen. One on the vertical portion may be so well marked as to produce an hour-glass contraction of the stomach. Another, 2 cm. to 3 cm. from the pylorus (see fig. 88), was termed by His the *sulcus intermedius.* Such depressions are of a transitory nature.

Dimensions.—These vary greatly in different subjects, and also according to the state of distension of the organ. When moderately filled, its length, measured from the top of the fundus to the lowest part of the great curvature, is about 20 cm. to 22 cm., and its diameter at the widest part from 8 cm. to 9 cm. The distance between its two orifices varies from 7 cm. to 15 cm. Its capacity varies so much, according to the dietetic habits of the individual and the degree of tonicity of its muscular coat and that of the abdominal wall, that it is difficult to give an average. It may appear moderately distended when it contains about 400 c.c., and, on the other hand, may readily accommodate several litres.

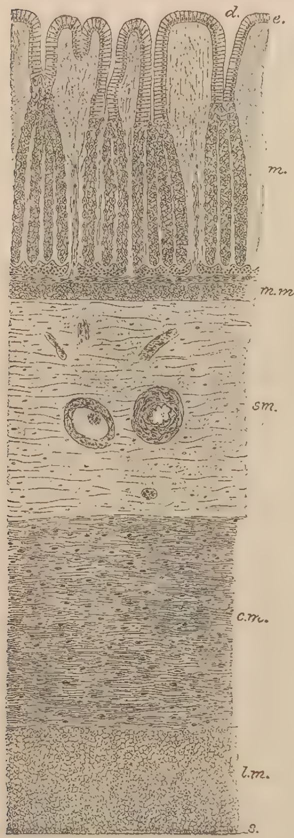


FIG. 97.—SECTION THROUGH THE COATS OF THE STOMACH. Diagrammatic. (Mall.)

m., mucous membrane ; *e.*, epithelium ; *d.*, orifice of gland duct ; *m.m.*, muscularis mucosæ ; *sm.*, submucous coat ; *c.m.*, circular muscular layer ; *l.m.*, longitudinal muscular layer ; *s.*, serous coat.

Variations according to age.—In the new-born child, the stomach is small and usually empty. Its general form and position are very similar to that of the empty and contracted stomach in the adult; but in consequence of the large size of the left lobe of the liver, the whole of its anterior surface is covered by this organ. When it becomes distended, the movement of its pyloric portion towards the right side is probably impeded by the large size of the liver.

APPEARANCE AND NAKED-EYE STRUCTURE OF THE STOMACH.

The stomach has four coats : named, in order from without inwards, the serous, muscular, areolar or submucous, and mucous tunics (fig. 97).

The **external** or **serous coat** (*tunica serosa*), derived from the peritoneum, is a thin, smooth, transparent and elastic membrane, which closely covers the entire viscus, except along its two curvatures and a variable extent of its posterior surface. Along the curvatures, the attachment of the peritoneum is looser, leaving an interval occupied by the large blood-vessels.

The second, **or muscular coat** (*tunica muscularis*), is composed of plain muscular tissue ; three sets of fibres, disposed in layers, and named, from their direction, the longitudinal, the circular, and the oblique fibres.

The first or outermost layer consists of the *longitudinal* fibres fig. 97, *l.m.*, fig. 98, *A*), which are in direct continuity with those of the œsophagus. They spread out in a radiating manner from the cardiac orifice, and are found in greatest abundance along the curvatures—especially the lesser one. On the anterior and posterior surfaces, they are very thinly scattered, or scarcely to be found, but, towards the pylorus, are well marked and form a uniform layer, which, at the pylorus,

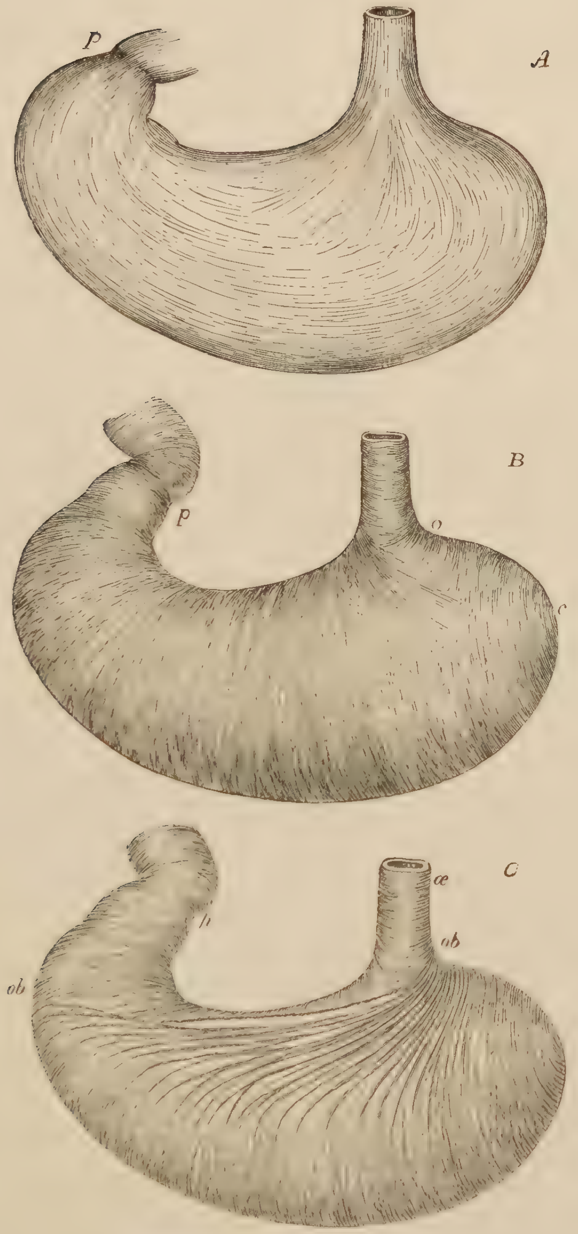


FIG. 98.—SKETCH OF THE ARRANGEMENT OF THE FIBRES IN THE MUSCULAR COAT OF THE STOMACH. One-third natural size. (Allen Thomson.)

A, external layer of longitudinal fibres, as seen from the outside; *B*, middle layer of circular fibres as seen on removing the longitudinal layer; *C*, oblique fibres exposed by removing some of the fibres of the circular layer, the cut edges of which are seen below the small curvature.

c, the cardiac end; *p*, the pyloric end; in *A* are shown the stronger longitudinal fibres, passing along the small and large curvatures, and all round the pyloric end, and radiating from the end of the gullet over the front (and back) of the stomach; in *B*, the nearly uniform layer of circular fibres, in two sets crossing each other very obliquely at *o*, and at the cardiac end becoming concentric to the centre of the fundus in *C*, the oblique fibres, *ob*, *ob′*, which form a continuation of the circular fibres of the gullet (*œ*), and spread from the left side of the cardiac, gradually merging into the deeper circular fibres, with which finally they entirely blend.

splits up into a superficial set of fibres continuous with the longitudinal fibres of the duodenum, and a deeper set which 'turn into the sphincter-ring, and there spread out in the form of diverging fasciculi, many of which reach the subjacent mucosa' (Cunningham, 'Trans. Royal Soc. of Edinburgh,' vol. xlv., 1906).

The second set consists of the *circular* fibres (fig. 97, *c.m.*; fig. 98, *B*), which form a complete layer over the whole extent of the stomach, except the fundus. This layer gradually becomes thicker as it passes towards the pylorus. If the pyloric part of the stomach is contracted, the fibres form a layer 2 mm. to 3 mm. in thickness, which ends at the pylorus to form the pyloric sphincter. According to Cunningham, these sphincter fibres are not continuous with the circular fibres of the duodenum. At the cardia, the superficial circular fibres of the lower end of the right side of the œsophagus pass obliquely downwards on the anterior and posterior surfaces of the stomach, and gradually blend with the circular fibres of the middle layer and also with the internal layer.

The innermost muscular layer forms what are known as the oblique fibres; but Birmingham[1] states that the majority of its fibres are circular, and surround the fundus in the same way as the circular fibres of the middle layer invest the rest of the stomach. At the cardia, these circular fibres become continuous with the oblique fibres, which form a loop at the incisura cardiaca and pass downwards and outwards over the two surfaces of the stomach, and blend with the circular fibres of the middle layer. These oblique fibres are best seen by the removal of the mucous membrane.[2]

The **submucous coat** (*tela submucosa*) is a distinct layer connecting the muscular and mucous coats (fig. 97, *sm.*). It consists of areolar tissue, in which occasional fat-cells may be found; and it is the seat of division and passage of the blood-vessels.

The **internal coat** or **mucous membrane** is a smooth, soft, rather thick and pulpy membrane, which in the fresh state has generally a somewhat pink hue, owing to the blood in its capillary vessels. In infancy, the vascular redness is more marked.

The mucous membrane is thickest in the pyloric region, and thinnest in the great cul-de-sac. It always becomes thinner in old age.

It is connected with the muscular coat, by means of the intervening submucous layer, so loosely as to allow of considerable movement or displacement. In consequence of this, and of the want of elasticity of the mucous membrane, the internal surface of the stomach, when that organ is in an empty or contracted state, is thrown into numerous convoluted ridges—*rugæ*—which are produced by the wrinkling of the mucous, together with the areolar coat, and are entirely obliterated by distension of the stomach. These folds have a general longitudinal direction—especially along the lesser curvature from the cardia to the incisura angularis, and in the pars pylorica. The folds parallel to the lesser curvature form the *canalis gastricus* (*Magenstrasse* of Waldeyer). Two elevations of the mucous membrane are found opposite the incisura cardiaca and incisura angularis.

When the pyloric canal is closed, the longitudinal folds of its mucous membrane terminate abruptly at the duodenum, and form a prominence into the duodenum, surrounded by a groove and bounding a stellate orifice (see fig. 94, *a*). If the stomach and duodenum are distended, the junction between their cavities is indicated by an annular projection of the mucous membrane and of the circular

[1] 'The Arrangement of the Muscular Fibres of the Stomach,' *Jour. of Anat. and Phys.*, vol. xxxiii., Oct. 1898.

[2] G. Schwalbe, 'Beiträge zur Kenntnis des menschlichen Magens,' *Zeitschrift für Morphologie und Anthropologie*, Sonderheft i., 1912.

muscular fibres, bounding a round or oval aperture, which seldom exceeds 12 mm. in diameter.

On examining the gastric mucous membrane closely, with the aid of a simple lens, it is seen to be marked throughout—but more plainly towards the pyloric extremity—with small depressions, which have a polygonal figure, and vary from about 0·12 mm. to 0·25 mm. across, being larger and more oblong near the pylorus.

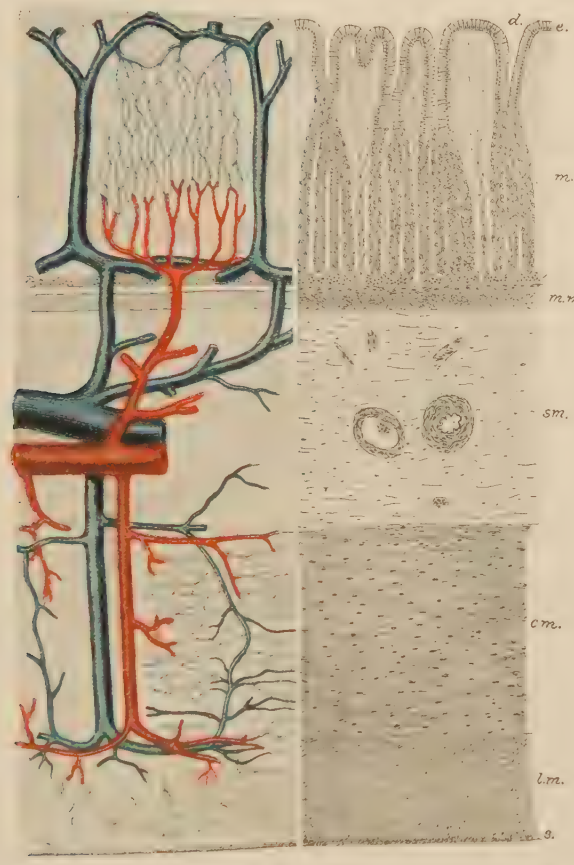


FIG. 99.—SECTION THROUGH THE COATS OF THE STOMACH TO SHOW THE ARRANGEMENT OF THE PRINCIPAL BLOOD-VESSELS. (Mall.)

On the right side of the figure the glandular and muscular elements are shown; on the left only the blood-vessels. It will be seen that the principal vessels are in the submucous tissue, and that from these, branches are distributed to the mucous membrane and to the muscular coat.

They are the enlarged mouths or ducts of the tubular glands with which the mucous membrane of the stomach is beset.

Towards the pyloric region of the stomach, these depressions are larger and deeper, and their margins are elevated into pointed processes, which resemble—especially in vertical section—rudimentary villi; but the perfect forms of those appendages exist only in the small intestine, and make their appearance in the duodenum immediately beyond the pylorus.

Blood-vessels, lymphatics, and nerves. The stomach is a highly vascular organ. Its **arterial** branches, derived from all three divisions of the *cœliac artery*, reach the stomach between the folds of the peritoneum, and form, by anastomosing together, two principal arterial arches, which are placed along its

two curvatures. Their branches pass through the muscular coat (to which, in passing, they give off some arterioles), and divide into smaller vessels in the submucous areolar tunic, where they also freely anastomose, and whence they are distributed to the mucous membrane and to the muscular layers. The arterial branches (fig. 99), which enter the mucous membrane, pass between the tubuli, ramifying freely in a radial manner; here they form a plexus of fine capillaries upon the walls of the tubuli; and from this plexus, larger vessels pass into a coarser capillary network around the mouths of the glands. The **veins**, fewer in number than the arteries, arise from the latter network, and take an almost straight course, through the mucous membrane between the glands, and join to form a plexus of larger vessels near the bases of the glands. From this plexus, pass off branches, which, after piercing the muscularis mucosæ and forming a wide venous plexus in the submucous tissue, return the residual blood into the splenic and superior mesenteric veins, and also directly into the vena portæ. These veins, as well as other tributaries of the vena portæ, have a particularly well-marked muscular coat, and contain numerous valves (Hochstetter).

The **lymphatics** are very numerous. As shown by Lovén, they arise in the mucous membrane by a dense network of lacunar spaces, situated between and amongst the gland-tubuli, which, as well as the blood-vessels, in many parts they enclose in sinus-like dilatations. Near the surface of the membrane, the lymph is collected into vessels which form loops or possess dilated extremities: these vessels are less superficial than the blood capillaries. At the deeper part of the mucous membrane, the interglandular lymphatics pass into a plexus of fine vessels immediately underlying the tubular glands; then piercing the muscularis mucosæ, they form a coarser, more deeply seated network in the submucous coat, the vessels of this network being provided with valves. Thence afferent lymphatics proceed, and, piercing the muscular coats, follow the direction of the blood-vessels beneath the peritoneal investment. The areas drained by these afferent lymph-vessels closely correspond with the areas supplied by the arteries, and they follow the course of these blood-vessels as far as their termination. The afferent lymphatics from the glands, on the other hand, leave the vessels and pass towards the cisterna chyli.

Numerous lymphatic glands are found in close relation with the stomach. The most important group is situated along the lesser curvature. The glands of this set are most numerous towards the upper end of the curvature, where the left gastric artery gives off its œsophageal branch. A chain of small glands surrounds the cardiac end of the stomach—most of them in front and on its right and left sides. The glands associated with the splenic artery are few in number, and are mainly situated along the upper border of the tail and body of the pancreas. A number of glands is found in relation to the branches of the hepatic artery distributed to the stomach. As a rule, there are no glands on the right gastric artery, but four or five glands are usually found on the gastro-duodenal artery, and rather more in the great omentum just below the right gastro-epiploic artery. (For further particulars regarding the lymphatics of the stomach, consult Jamieson and Dobson, 'The Lymphatic System of the Stomach,' *Lancet*, April 20, 1907.)

The **nerves**, which are large, consist of the terminal branches of the two vagi nerves, belonging to the cerebro-spinal system, and of offsets from the sympathetic system, derived from the cœliac plexus. The left vagus nerve descends on the front, and the right upon the back, of the stomach, and both nerves are here composed almost entirely of non-medullated nerve-fibres. Numerous small ganglia have been found by Remak and others on both the vagus and sympathetic twigs.

The nerves form gangliated plexuses (like the myenteric and submucous plexuses of the intestine), both between the layers of the muscular coat and in the submucous coat. From these plexuses, nerve-fibrils proceed to the muscular tissue and to the mucous membrane.

Varieties.—In complete transposition of the viscera, the stomach will of course lie on the right side. Congenital hour-glass contraction of the stomach is rare. This contraction is often met with in the adult, without any signs of disease, and it is due to a localised temporary, or physiological, contraction of the circular muscular fibres. Congenital stenosis of the pylorus occasionally occurs.

INTESTINUM TENUE.

The small intestine (*intestinum tenue*) commences at the pylorus, and, after many convolutions, terminates in the large intestine. According to Treves, it measures, on an average, about 7 metres (22½ feet) in length in the adult, and becomes gradually narrower from its upper to its lower end.

Treves (*The Anatomy of the Intestinal Canal and Peritoneum in Man*, 1885) made his measurements on fresh material, in which the bowel is very distensile. Sernoff (' Zur Kenntnis der Lage und Form des mesenterialen Teiles des Dünndarmes,' *Internat. Monatsch. f. Anat. und Phys.*, Bd. xi., Heft 10), found, in hardened subjects, the length to be on an average 5·3 metres.

Its convolutions may extend into all the regions of the abdomino-pelvic cavity situated below the transpyloric plane of Addison, and they are sometimes found reaching upwards above this plane, especially on the left side.

The small intestine is divided into three portions, which have received different names. The first ten or twelve inches immediately succeeding to the stomach, and comprising the widest and most fixed part of the tube, is called the *duodenum*. This part is further distinguished by its close relation to the head of the pancreas and by the absence of a mesentery. The remainder, which is arbitrarily divided into an upper two-fifths called the *jejunum*, and a lower three-fifths called the *ileum*, is very convoluted and movable, being connected with the posterior abdominal wall by a long and extensive fold of peritoneum called the mesentery, and by numerous blood-vessels and nerves. Although there is no distinct line of demarcation between the jejunum and the ileum, yet the portion of the small intestine included under these two names gradually undergoes certain changes in structure and appearance from above downwards, so that the upper end of the jejunum can readily be distinguished from the lower part of the ileum.

POSITION AND RELATIONS OF THE SEVERAL PARTS OF THE SMALL INTESTINE.

Duodenum.—This is the shortest and widest part of the small intestine. In length it measures about 25 cm. to 30 cm., and in diameter 3·5 cm. to 5 cm. In its course, it describes a single large curve, which, when the stomach is empty, forms an almost complete ring, its termination in the jejunum being only a little to the left of its commencement (Braune). Distension of the stomach, and the consequent movement of the pylorus towards the right side, makes the curve of the duodenum U-shaped rather than annular. The curve of the duodenum does not all lie in one plane: for, while the commencement of the first part, the greater portion of the third and the fourth parts, occupy a coronal plane, the termination of the first part, the second part, and the beginning of the third, bend backwards on the right side of the inferior vena cava and occupy approximately a sagittal plane.[1] The concavity embraces the head of the pancreas.

[1] A. Birmingham, 'The Topographical Anatomy of the Spleen,' &c., *Jour. Anat. and Phys.*, vol. xxxi., 1897.

It has no mesentery, and is covered only partially by peritoneum. Its muscular coat is comparatively thick, and its submucous layer towards the pylorus is the seat of the glandulæ duodenales or the glands of Brunner. The common bile-duct and the pancreatic duct open into this part of the intestinal canal.

The duodenum may be divided, for the purpose of anatomical description, into four parts.

The first, or **pars superior**, is the most variable in length and direction, since, while its termination is fairly fixed in position, the pylorus, from which it starts,

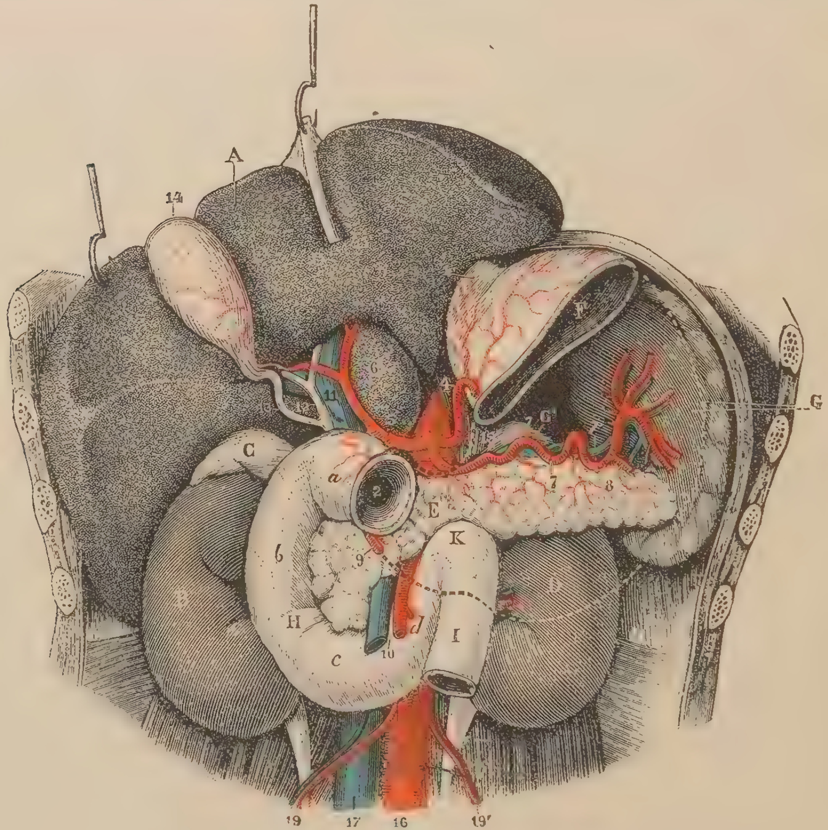


Fig. 100.—View of the duodenum, pancreas, spleen, etc. (Testut.)

The greater part of the stomach has been removed, exposing the posterior relations.

A, inferior surface of liver; B, right kidney; C, C′, right and left suprarenal glands; D, left kidney; E, pancreas; F, upper part of stomach; G, spleen; H, duodenum with *a*, *b*, *c*, *d*, its four portions; I, jejunum; K, duodeno-jejunal junction; 1, lower end of œsophagus; 2, pyloric orifice; 3, cœliac artery; 4, coronary artery; 5, hepatic artery; 6, lobus caudatus of liver; 7, 7′, splenic vessels; 8, left gastro-epiploic artery; 9, right gastro-epiploic artery; 10, superior mesenteric vessels; 11, portal vein; 12, hepatic duct; 13, cystic duct; 14, gall-bladder; 15, left crus of diaphragm; 16, aorta; 17, inferior vena cava; 18, inferior mesenteric vessels; 19, 19′, spermatic vessels.

is relatively mobile. If the pylorus lies below the inferior border of the anterior surface of the liver, or only slightly overlapped by this organ, and is also placed somewhat to the right of the median plane, the main direction of the superior part will be backwards and upwards; whereas if the pylorus is well under cover of the liver and in the median plane, or somewhat to the left of this plane, the direction of this part will be at first mainly to the right, and only towards its termination will it incline backwards. The anterior surface may be in contact with the anterior

abdominal wall before reaching the under-surface of the liver, while in other cases its whole extent may be in contact with the quadrate lobe. Behind it are the pancreas, the portal vein, the gastro-duodenal artery, and the common bile-duct. The first part ends close to the neck of the gall-bladder.

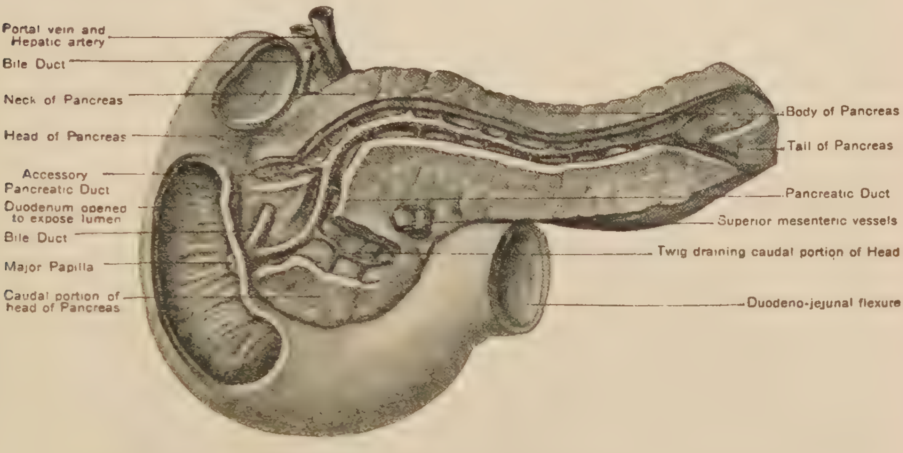


FIG. 101.—DUODENUM AND PANCREAS, VIEWED FROM THE FRONT. (W. M. Baldwin.)

The second, or **pars descendens**, is about 8 cm. long. It commences just below the neck of the gall-bladder, opposite the right side of the first lumbar vertebra, and passes down to the level of the body of the third or fourth lumbar vertebra,

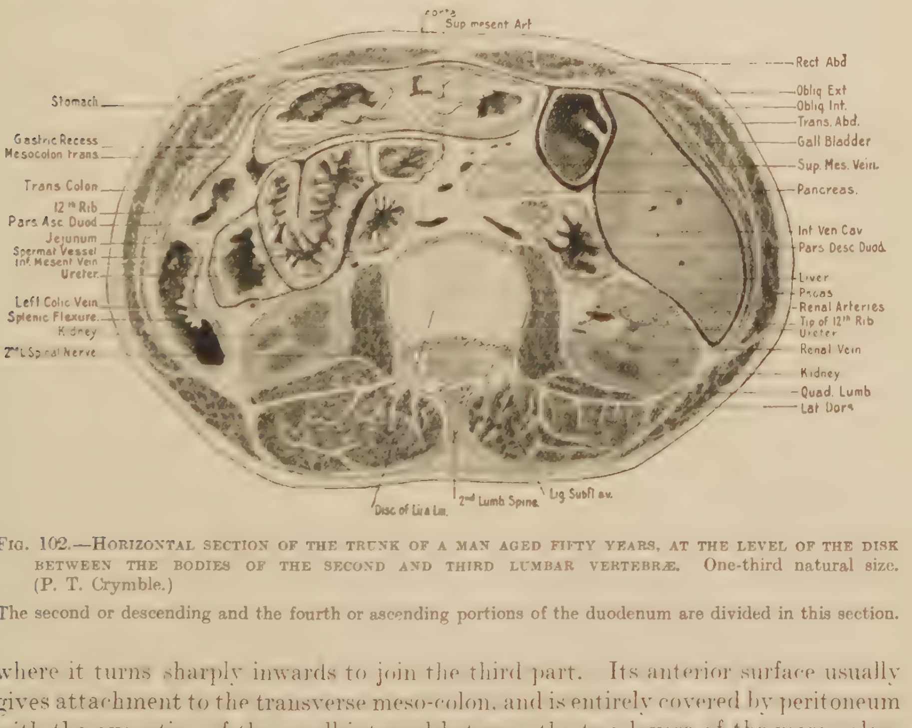


FIG. 102.—HORIZONTAL SECTION OF THE TRUNK OF A MAN AGED FIFTY YEARS, AT THE LEVEL OF THE DISK BETWEEN THE BODIES OF THE SECOND AND THIRD LUMBAR VERTEBRÆ. One-third natural size. (P. T. Crymble.)

The second or descending and the fourth or ascending portions of the duodenum are divided in this section.

where it turns sharply inwards to join the third part. Its anterior surface usually gives attachment to the transverse meso-colon, and is entirely covered by peritoneum with the exception of the small interval between the two layers of the meso-colon. This small uncovered area is sometimes considerably increased, owing to the

transverse colon being here destitute of a meso-colon, and separated from the duodenum by areolar tissue only. Above the transverse colon, the anterior surface is in contact with the liver. The posterior surface has no peritoneal covering, but is connected by areolar tissue to the right kidney and its vessels and the ureter and the psoas muscle. There are considerable variations in the relations of the second part of the duodenum to the right kidney. According to Cunningham, they are probably due rather to variations in the position of the kidney than of the duodenum. As a rule, the duodenum comes in contact with the kidney a little above its hilum, and reaches down to about the level of its lower end. To the left is the head of the pancreas (see fig. 101), which adapts itself to the shape of

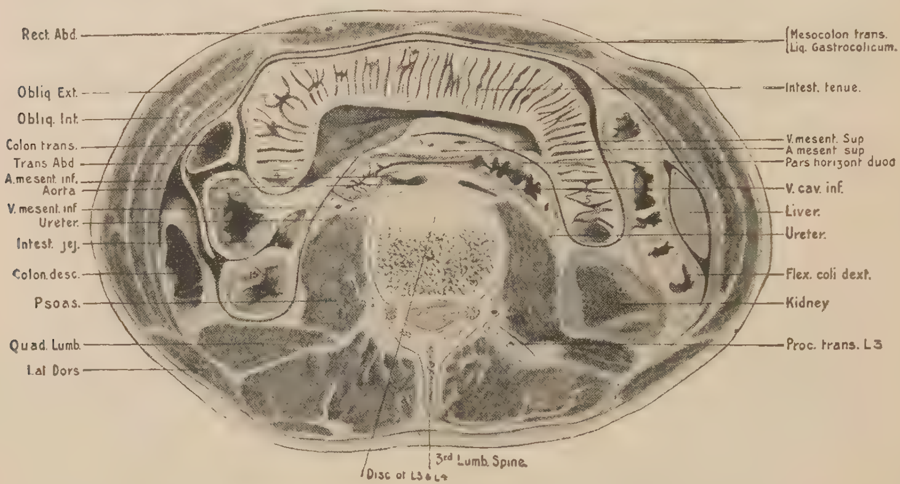


FIG. 103.—HORIZONTAL SECTION OF THE TRUNK OF A MAN, AGED FIFTY YEARS, AT THE LEVEL OF THE DISK BETWEEN THE THIRD AND FOURTH LUMBAR VERTEBRÆ. One-third natural size. (P. T. Crymble.) The third or horizontal part of the duodenum is divided in this section.

the intestine on that side, and, according to Verson, some of the longitudinal fibres of the gut are intercalated amongst the contiguous lobes of the gland. The common bile-duct descends behind the left border of this part of the duodenum, and the pancreatic duct accompanies it for a short distance.

The third, or **pars horizontalis**, of the duodenum is between 6 cm. and 8 cm. long. Beginning on the right of the third or fourth lumbar vertebra, it crosses over to the left side, with a slight upward inclination, and ends to the left of the aorta by curving upwards to join the ascending or terminal part of the duodenum. Its anterior surface is covered by peritoneum at its commencement; but near the median plane, it becomes separated from the anterior layer of the mesentery by the superior mesenteric vessels, which groove its anterior surface. Behind, it lies against the right psoas muscle, the inferior vena cava, the aorta, and the left psoas muscle. On the right side, its posterior surface is uncovered by peritoneum; but towards the left, the posterior parietal peritoneum is sometimes prolonged upwards, behind it, for a variable distance. Above it is the head of the pancreas.

The fourth, or **pars ascendens**, is about 5 cm. long. It passes upwards on the left side of the aorta as high as the upper border of the second lumbar vertebra, where it turns abruptly forwards to join the jejunum, forming the *duodeno-jejunal flexure*. It is covered in front and on the left side by the peritoneum, which often forms on its left side one or two peritoneal pouches called the duodenal fossæ, and it lies behind the transverse meso-colon, which usually separates it from the

stomach, although some convolutions of the jejunum may intervene (fig. 102). It rests on the left psoas muscle—the inner margin of the left kidney is sometimes slightly overlapped by it—and near its upper end the left renal vein passes behind it.

From its peritoneal relations, the duodenum may be divided into two portions—*pars supra-colica* and *pars infra-colica*. The supra-colic part is situated above the line of attachment of the transverse meso-colon, and includes the first and the upper part of the second portion of the duodenum; while the infra-colic is below this line, and comprises the remaining portion of the duodenum. The pars infra-colica may be subdivided into a right, a sub-mesenteric, and a left portion (Waldeyer, 'Die Kolon-Nischen, u.s.w.,' *Abh. d. k.p. Akad. d. Wissensch. zu Berlin*, 1900). The first part of the duodenum has been called sub-hepatic, the second the præ-renal, and the third the præ-aortic. (Jonnesco, 'Sur l'anatomie topographique du duodénum,' *Bull. de la Soc. Anat. de Paris*, 1889).

Musculus suspensorius duodeni.—The fixation of the upper end of the terminal part of the duodenum is largely affected by a band composed of fibrous and muscular tissue, which connects it with the right crus of the diaphragm, and is known as the musculus suspensorius duodeni of Treitz.[1] This band has a left free border, lateral to which is the inferior mesenteric vein, and on the right side it is continuous with a layer of fibrous tissue which extends below, partly into the mesentery and partly into the concavity of the duodenum. When traced upwards, it is found to form a small elastic tendon, which lies to the left of the origins of the superior mesenteric and cœliac arteries and in front of the cœliac plexus. This tendon ends in a muscular bundle, which springs from the right crus of the diaphragm, and is composed partly of striped fibres. Crymble[2] suggests that during development it may pull the duodeno-jejunal flexure round the superior mesenteric artery to its final position. Just above this flexure the muscle is covered by a fold of peritoneum named the *plica duodeno-jejunalis*.

Varieties.—The position of the duodenum does not vary greatly. According to Fawcett and Blatchford (*Jour. Anat. and Phys.*, vol. xxxviii., July 1904), the third portion generally crosses in front of the third lumbar vertebra, and not infrequently it is as low as the fourth; but it is rare for it to come into relation with the fifth lumbar. Thus out of 337 subjects, in only three did it reach this level. In four of their cases the duodenum ended on the right side of the vertebral column.

Duodenal diverticula are not very uncommon. They are usually single, consist of all the coats of the intestine, and project from the concave side of the duodenum, and, consequently, towards the pancreas. Descriptions of a number of specimens, and the literature of the subject, are given by W. M. Baldwin ('Duodenal Diverticula in Man,' *The Anatomical Record*, vol. v., 1911).

The duodenum is one of those portions of the alimentary canal which, during embryonic life, is liable to physiological occlusion by proliferation of its epithelial lining. This may persist as an atresia or become the seat of a stenosis.

Jejunum and ileum.—The jejunum, originally so called from its having been supposed to be empty after death, follows the duodenum, and includes the upper two-fifths of the remainder of the small intestine, while the succeeding three-fifths constitute the ileum—so named from its numerous coils and convolutions. Both the jejunum and the ileum are attached to the posterior abdominal wall by an extensive fold of peritoneum, termed *the mesentery*. This mesentery, although greatly frilled out in front to correspond in length with the jejunum and ileum to which it gives support, is attached posteriorly by a comparatively short border (about 15 cm.), which extends from the left side of the second lumbar vertebra obliquely across the third part of the duodenum, the aorta, the inferior vena cava, and the right psoas muscle to the right iliac fossa, where it ends. The length of the mesentery, measured from the parietal attachment to the intestine, varies—being longer about the middle than at either end of the bowel. The average length, according to Treves,[3] may be taken as eight to nine inches (20 cm. to 22·5 cm.). Lockwood[4] found that, up to the age of forty years, it rarely exceeded

1 'Ueber einen neuen Muskel am Duodenum des Menschen,' *Vierteljahrschrift für die praktische Heilkunde, Prag.*, 1853, Bd. xxxvii.

2 'The Muscle of Treitz and the Plica Duodeno-jejunalis,' *Brit. Med. Jour.*, October 15, 1910.

3 *The Anatomy of the Intestinal Canal and Peritoneum in Man*, 1885.

4 'Hunterian Lectures on the Morbid Anatomy, Pathology, and Treatment of Hernia,' *Brit. Med. Journal*, June 15, 1889.

8 inches (20 cm.); but, after this period of life, longer mesenteries occurred with greater frequency. Where the ileum crosses the right psoas, the mesentery is usually very short, and sometimes absent, so that this part of the intestine is only slightly movable. Between the two layers of the peritoneum, forming the mesentery, are placed—besides some fat—numerous branches of the superior mesenteric artery and vein, together with nerves, lacteal vessels, and lymphatic glands. The convolutions of the jejuno-ileum occupy parts of the umbilical and hypogastric zones of the abdomen, and a variable number of loops lie in the pelvis. Owing to the size and position of the liver, the greater part of the jejuno-ileum lies to the left of the median plane. A considerable number of the convolutions are usually in direct relation with the anterior abdominal wall; but they may be separated from it by the lower part of the stomach, part of the transverse and pelvic colons, the great omentum, and the upper part of a distended bladder. When the stomach passes downwards in front of some of the convolutions, the transverse colon intervenes. The liver, spleen, pancreas, suprarenal glands, upper ends of the kidneys, and the stomach usually occupy the upper part of the abdomen to the exclusion of the jejuno-ileum. The convolutions of the small intestine often lie in front of the lower ends of the two kidneys, the ascending, descending, and iliac colon, and sometimes the cæcum; and in the pelvis may rest against any parts of the pelvic viscera which have a peritoneal covering.

The character of this portion of the small intestine gradually changes from its upper to its lower end, so that portions of the jejunum and ileum, remote from each other, present certain well-marked differences of structure, which will be described in the account of their structure. The jejunum is larger than the ileum, and its coats are thicker and more vascular. The diameter of the jejunum when moderately distended is about 4 cm.; and that of the ileum 3 cm. According to Chaput and Lenoble,[1] the lower end of the ileum will not pass a structure having a diameter of more than 25 mm.

On account of the length of their mesentery and their almost complete investment by peritoneum, the coils of the jejuno-ileum are freely movable—not merely as a whole, but upon one another. It is generally admitted that, owing to the fixation of the two ends of the jejuno-ileum, and to the line of attachment posteriorly of their mesentery passing from above and on the left side downwards and to the right, the jejunum will tend to lie above and to the left of the ileum. The convolutions that pass into the pelvis belong mainly, but not exclusively to the ileum, as the lower attachment and the length of its portion of the mesentery readily admit of such a descent. The terminal portion of the ileum goes upwards and to the right, and crosses the right psoas muscle to join the large intestine.

Various attempts have been made to ascertain whether or not the individual coils of the jejuno-ileum are arranged on a definite plan. Treves[2] failed to find satisfactory evidence of such a plan. Henke[3] came to the conclusion that the upper part of the jejuno-ileum was situated on the left side, and formed horizontally directed folds, while the lower part was on the right side, and its convolutions were vertical. Sernoff[4] could not confirm the conclusions of Henke, but Weinberg,[5] from an examination of ten newly born children, supported them. Weinberg found the first two-fifths of the jejuno-ileum in the upper and left side of the abdomen and the convolutions were generally horizontal in direction. The next fifth was situated in the left iliac fossa, and its convolutions had no regular direction. It terminated by crossing the left psoas muscle to join the remaining two-fifths, which were found between the two psoas muscles and in the right half of the abdomen, and their convolutions were, as a rule, arranged vertically. About one-third of the whole length of the jejuno-ileum was in contact with the anterior abdominal

[1] 'Étude sur le Calibre normale de l'Intestin grêle,' *Bulletins de la Soc. Anat. de Paris*, 69 Année, 1894.

[2] *The Anatomy of the Intestinal Canal and Peritoneum in Man*, 1885.

[3] 'Der Raum der Bauchhöhle des Menschen und die Verteilung der Eingeweide in demselben,' *Arch. f. Anatomie*, 1891.

[4] 'Zur Kenntnis der Lage und Form des mesenterialen Teiles des Dünndarmes,' *Internat. Monatsch. f. Anat. und Phys.*, Bd. xi., Heft 10.

[5] 'Topographie der Mesenterien und der Windungen des Jejunoileum,' *Internat. Monatsch. f. Anat. und Phys.*, Bd. xiii., Heft 2.

wall. The most important and extensive researches on this subject are those of Mall.[1] He traced the development of the loops of the small intestine during fetal life, and examined a considerable number of adults. In the fifth or sixth week of embryonic life, the small intestine exhibits six slight curves, which he numbers 1 to 6. These primary curves or loops gradually increase in size, and, except the first, which forms the duodenum, become complex by the formation of secondary loops, but can be recognised throughout life. No. 2 passes to the left, and its convolutions occupy the left side of the abdomen below the left half of the transverse colon. No. 3 also forms a loop towards the left, and it lies with its secondary folds on the left side below those of no. 2. The lower limb of loop 3 passes across the median plane, and no. 4 forms a curve directed towards the right, and has its convolutions lying below the right of the transverse colon. No. 5 constitutes a series of convolutions which occupy the left side of the body and reach down into the pelvis, while the last portion, no. 6, extends upwards and to the right.

Varieties.– **Meckel's diverticulum.**—In about one in fifty subjects, a tubular or conical diverticulum is given off from the main tube of the ileum. Its average position above the ileo-colic opening is about 107·5 cm., but it has been found to vary from 27·5 cm. to 300 cm. It usually comes off from the ileum on the side opposite to the attachment of the mesentery. As a rule, it is from 5 cm. to 7·5 cm. in length, and about the same calibre as the bowel, from which it arises. This diverticulum is due to the persistence of a part of the vitelline duct of early fetal life. It is very rarely attached to the umbilicus. Mitchell found it in 39 out of 1635 necropsies. (For further particulars, consult A. Thomson, 'Diverticulum ilei,' *Jour. Anat. and Phys.*, vol. xxvi., 1892; and Mitchell, 'Notes on a Series of Thirty-nine Cases of Meckel's Diverticulum,' *Jour. Anat. and Phys.*, vol. xxxii., 1898.) It is not to be confounded with hernial protrusions of the mucous membrane, which may occur at any point.

Variations with age and sex.—Treves found the average length of the small intestine in the new-born child to be 282·5 cm., and he estimates that it grows about 60 cm. during the first month of extra-uterine life and a similar amount in the second month; but after this period its rate of growth is very variable. Treves gives the average length of the small intestine in the adult female as 25 cm. longer than that of the male; but Rolssen, from measurements on German subjects, found it about 60 cm. longer in the male.

APPEARANCE AND NAKED-EYE STRUCTURE OF THE SMALL INTESTINE.

The small intestine, like the stomach, is composed of four coats: namely—the serous or peritoneal, muscular, submucous, and mucous.

The external or **serous coat** (*tunica serosa*) almost entirely surrounds the intestinal tube in the whole extent of the jejunum and ileum, leaving only a narrow interval behind, where it passes off and becomes continuous with the two layers of the mesentery. The line at which this takes place is named the *attached* or *mesenteric border* of the intestine. The serous coat is very thin and translucent, and the subserous areolar tissue small in amount, so that the muscular fibres are visible from the outer aspect. There are no appendices epiploicæ (see fig. 125, *c*). The duodenum is but partially covered by the peritoneum, and has no mesentery.

The **muscular coat** (*tunica muscularis*) consists of two layers of fibres: an outer longitudinal, and an inner or circular set. The *longitudinal* fibres constitute an entire but comparatively thin layer, and are most obvious along the free border of the intestine. The *circular* layer is thicker and more distinct. Ochsner[2] describes a marked thickening of these fibres in the duodenum, from 3 cm. to 10 cm. below the opening of the common bile-duct.

The muscular tunic becomes gradually thinner towards the lower part of the small intestine. It is pale in colour, and is composed of plain muscular tissue, the cells of which are of considerable length. The progressive contraction of these fibres, commencing in any part of the intestine, and advancing in a downward direction, produces the peculiar *vermicular* or *peristaltic* movement by which the

[1] 'Ueber die Entwickelung des menschlichen Darmes und seiner Lage beim Erwachsenen,' *Arch. f. Anat.*, Ergänzungsband, 1897.

[2] 'Further Observations on the Anatomy of the Duodenum,' *American Journal of Medical Science*, vol. cxxxii., 1896.

contents are forced onwards through the canal. In the narrowing of the tube, the circular fibres are mainly concerned—the longitudinal fibres, shortening the tube, tend to produce dilatation (Exner), and those found along the free border of the intestine may have the effect of straightening or unfolding its successive convolutions. There is a gangliated plexus of nerve-fibres (*plexus myentericus*) and a network of lymphatic vessels between the two muscular layers.

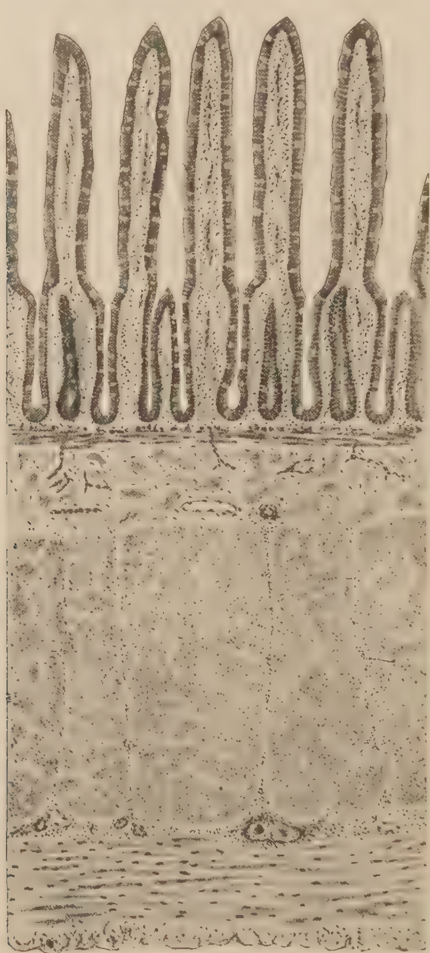


FIG. 104.—SECTION OF JEJUNUM OF CAT, PARALLEL TO THE LONG AXIS OF THE INTESTINE. Magnified forty diameters. (Schaefer.)

The **submucous coat** (*tela submucosa*) of the small intestine is a layer of areolar tissue of a loose texture, which is connected more firmly with the mucous than with the muscular coat. Within it the blood-vessels ramify before passing to the mucous membrane, and there is a gangliated plexus (*plexus submucosus*) of nerve-fibres and a network of large lymphatic vessels.

The internal coat, or **mucous membrane** (*tunica mucosa*), is characterised by the finely flocculent or shaggy appearance of its inner surface, resembling the pile upon velvet. This appearance is due to the surface being thickly covered with minute processes named *villi*. It is one of the most vascular membranes in the

body, and is naturally of a reddish colour in the upper part of the small intestine, but is paler, and at the same time thinner, towards the lower end. It is lined with columnar epithelium throughout its whole extent, and next to the submucous coat is bounded by a layer of plain muscular tissue (*muscularis mucosæ*); between this and the epithelium, the substance of the membrane—apart from the tubular glands (which will be afterwards described)—consists mainly of lymphoid tissue, which supports the blood-vessels, nerves, and lymphatics (lacteals), and encloses in its meshes numerous lymph-corpuscles.

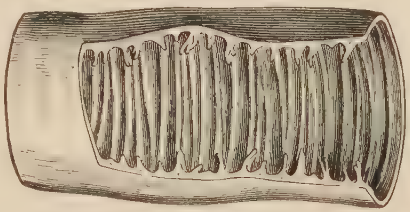


Fig. 105.—Portion of small intestine distended with alcohol, and laid open to show the plicæ circulares. (Brinton.)

Plicæ circulares (*valvulæ cónniventes*).—The mucous membrane, in addition to small effaceable folds or rugæ, possesses also permanent folds, which cannot be obliterated—even when the tube is forcibly distended. These permanent folds are the *valvulæ conniventes*, or *valves of Kerkring*. They are crescentic projections of the mucous membrane, placed transversely to the axis of the bowel, and following one another closely. The majority of the folds do not extend more than

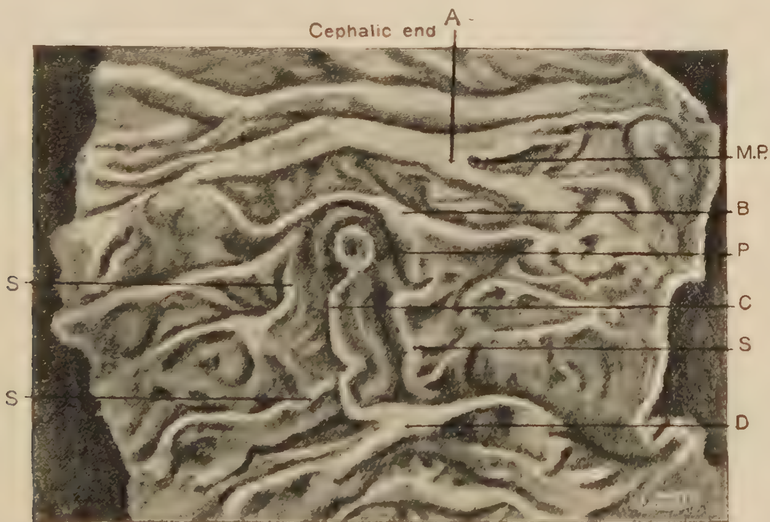


Fig. 106.—The second part of the duodenum opened. Natural size. (W. M. Baldwin.)

It shows the typical distribution of the 'primary' and 'secondary' folds of the duodenal mucosa in the region of the two papillæ.

M.P., minor papilla; P, depression containing the major papilla with the orifice of the bile and pancreatic ducts; C, plica longitudinalis duodeni; A, B, D, primary folds; S, S, S, secondary folds.

about one-half or two-thirds round the interior of the tube; but it has been shown by Brooks [1] and Kazzander [2] that some form complete circles, and others spirals. The spiral forms may occur singly or in groups of two or three. They generally extend a little more than once round the bowel, but in rare cases may go round two or three times. At their highest point, they project inwards for about a third of an

[1] 'On the Valvulæ Conniventes in Man, *Brit. Med. Journ.*, Feb. 1890.
[2] 'Ueber die Falten der Dünndarmschleimhant des Menchen,' *Anat. Anz.*, Bd. vii., 1892.

inch. Some of the plicæ circulares are bifurcated at one or both ends, and others terminate abruptly. Each consists of a fold of mucous membrane—that is, of two layers placed back to back, and united together by submucous areolar tissue. They contain no part of the circular or longitudinal muscular coats. Being extensions of the mucous membrane, they serve to increase the absorbent surface to which the food is exposed.

The plicæ circulares are not uniformly distributed over the various parts of the small intestine. There are none quite at the commencement of the duodenum; a short distance from the pylorus they begin to appear; beyond the point at which the bile and pancreatic juice are poured into the duodenum, they are very large, regularly crescentic in form, and placed so near to each other that the intervals between them are not greater than the breadth of one of the valves; they continue thus through the rest of the duodenum and along the upper half of the jejunum; below that point they begin to get smaller and farther apart, and, finally, towards the middle or lower end of the ileum, having gradually become more irregular and indistinct—sometimes even acquiring a very oblique direction—they altogether disappear.

Plica longitudinalis duodeni and papillæ duodeni.—On the median wall of the second part of the duodenum is a longitudinal fold of mucous membrane, upon the upper end of which is the papilla major with a central depression forming the orifice of the bile and main pancreatic ducts; while below, at about the union of the second and third parts of the duodenum, the fold joins a plica circularis. Proximal and ventral to the papilla major is the papilla minor on which opens the accessory duct of the pancreas (see figs. 101 and 106).

The **villi intestinales**, peculiar to the small intestine, and giving to its internal surface the velvety appearance already spoken of, are small processes of the mucous membrane, which are closely set on every part of the inner surface over the plicæ circulares, as well as between them.

Their length varies from 0·5 mm. to 0·7 mm., or sometimes more. They are largest and most numerous in the duodenum and jejunum, and become gradually smaller and fewer in number in the ileum. According to Rauber, they are short and leaf-shaped in the duodenum, and as the gut is followed downwards they become gradually longer and thinner, so that they are tongue-shaped in the jejunum, and filiform in the ileum. Occasionally, two or three are connected together at their base. In the upper part of the small intestine there are from ten to eighteen villi in a square millimetre, and in the ileum from six to fourteen in the same space. This would give a total of about four millions (Krause).

Glands.—Two kinds of small secreting glands open on the inner surface of the intestine: namely, the crypts of Lieberkühn and Brunner's glands—the last being peculiar to the duodenum. In addition to these, numerous lymphoid nodules are found, which are either scattered and isolated (solitary glands) or collected into patches (Peyer's glands).

Glandulæ intestinales (*crypts of Lieberkühn*), the smallest but most numerous of these glandular structures, are found in every part of the small intestine, opening on the surface between the villi.

Glandulæ duodenales (*Brunner's glands*) are small compound acino-tubular glands, which exist in the duodenum (where they are most numerous at the upper end); they occupy a space extending from 2·5 cm. to 5 cm. beyond the pylorus into the beginning of the jejunum. A few of them are also said to be found quite at the commencement of the jejunum. They are embedded in the submucous coat, and may be exposed by dissecting off the muscular coat from the outside of the intestine. They may extend partly into the mucous membrane between the crypts

of Lieberkühn. In structure, they somewhat resemble the small glands which are found in various parts of the lining membrane of the mouth and elsewhere, each consisting of a number of tubular alveoli, connected by the terminal ramifications of the duct, which latter penetrate the muscularis mucosæ, and open upon the inner surface of the intestine. The ducts open either between the crypts of Lieberkühn or, in some cases, into the bases of the crypts (Schaffer). In sections through the pylorus, the glands of Brunner appear like direct continuations of the pyloric glands of the stomach (Watney), which they closely resemble in structure, but they are somewhat more complicated and more deeply seated.

The **noduli lymphatici solitarii** (*solitary glands*) are soft, white, rounded, and slightly prominent bodies 0·6 mm. to 3 mm. in diameter, which are found scattered over the mucous membrane in every part of the small intestine. They are found as well at the mesenteric as at the free border, both between and upon the plicæ circulares, and are rather more numerous in the lower portion of the bowel.

The **noduli lymphatici aggregati** (*agminated glands* or *glands of Peyer*, who described them in 1677) are groups or patches of lymphoid nodules. The groups have an oblong figure (fig. 107), and vary from half an inch to two or even four inches in length, and from half an inch to about an inch in width (12 mm. to 120 mm. long and 12 mm. to 25 mm. broad). They are placed lengthways in the intestine, at that part of the tube most distant from the mesentery, and hence, to obtain the best view of them, the bowel should be opened by an incision along its attached border.

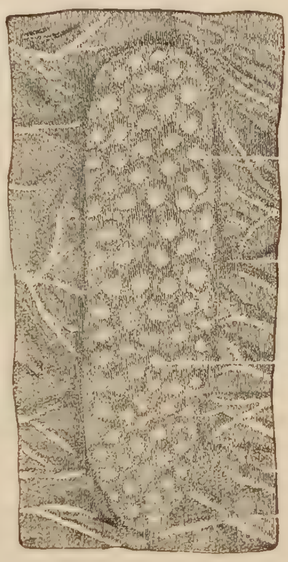


FIG. 107.—A SMALL PATCH OF PEYER'S GLANDS, OR NODULI LYMPHATICI AGGREGATI, FROM THE ILEUM. Slightly magnified. (Boehm.)

The lymphoid nodules, which by their aggregation make up a Peyer's patch, are in almost all respects similar to the solitary glands above described. As a rule, their surface is free from villi, and the crypts of Lieberkühn are collected in circles around them. Fine blood-vessels are distributed abundantly on the exterior of the follicles, and give off still finer capillary branches, which, supported by the retiform tissue, are disposed principally in lines converging to the centre.

Blood-vessels, lymphatics, and nerves.—The **arterial** supply of the small intestine is derived entirely from the superior mesenteric, with the exception of the duodenal branches of the superior pancreatico-duodenal artery which go to the upper part of the duodenum, the lower part being supplied by the inferior pancreatico-duodenal of the superior mesenteric. As the blood in the superior pancreatico-duodenal comes through the gastro-duodenal and hepatic arteries from the cœliac artery, there is an area on the duodenum representing the boundary between the intestinal distribution of the cœliac and superior mesenteric arteries. The upper and by far the greater part of the jejuno-ileum is supplied by the jejunal and ileal branches (rami intestini tenuis) of the superior mesenteric; below these branches, the arterial supply is completed by the termination of the superior mesenteric, and twigs from the ileo-colic. The branches to the jejuno-ileum form a number of anastomosing arcades, and the terminal branches, when they reach the mesenteric border of the intestine,

divide into two vessels, which encircle the bowel. The **veins**, which in the adult are almost destitute of valves,[1] correspond generally to the arteries, but they terminate in the portal vein.

The **lymphatic** vessels, or lacteals, of the small intestine arise in the villi, and

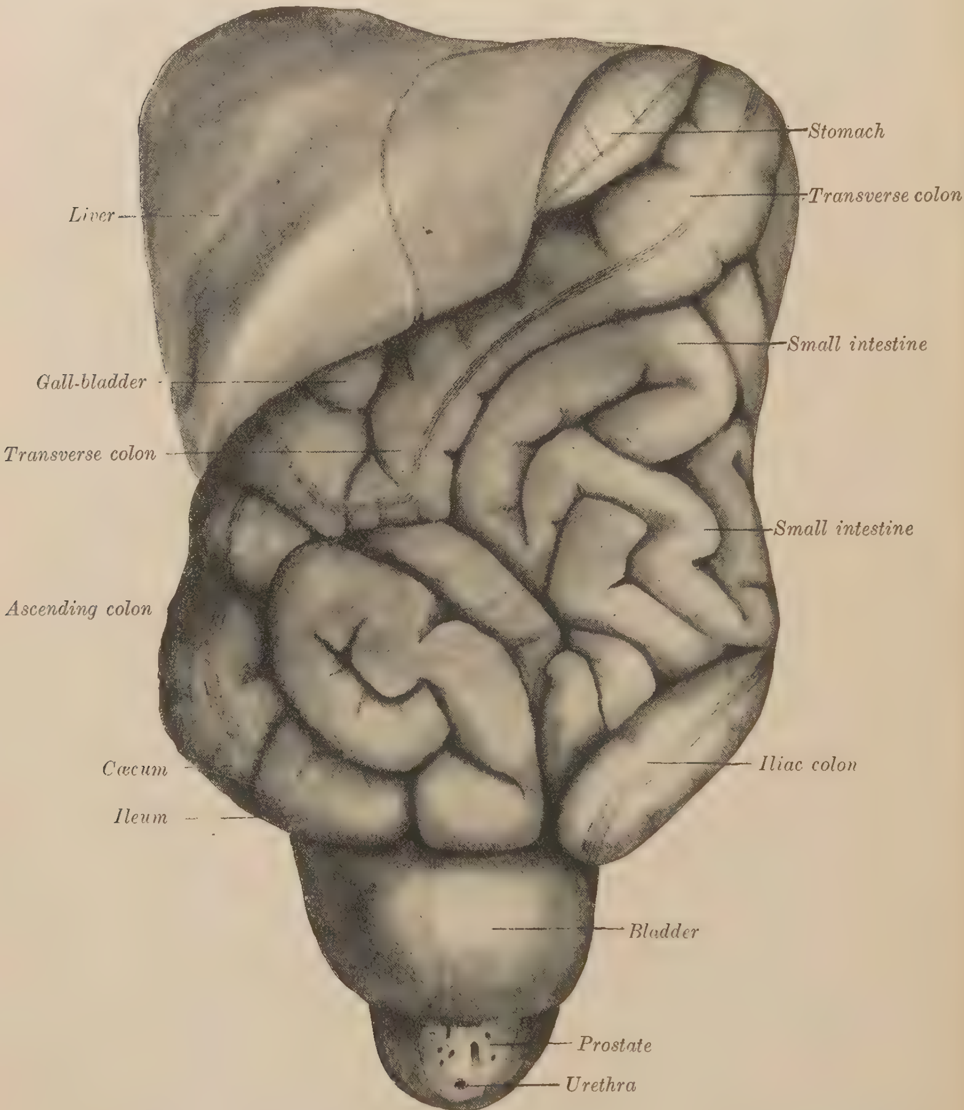


FIG. 108.—THE ABDOMINO-PELVIC VISCERA OF A MAN AGED FIFTY-ONE YEARS, VIEWED FROM FRONT. One-third natural size. (J. Symington.)

form a mucous, a submucous, a muscular, and a subserous plexus. The vessels which pass from the jejunum and ileum ascend between the two layers of the mesentery, and enter the mesenteric glands, which are situated in the mesentery, mainly along the course of the blood-vessels, and in its root. The vasa efferentia

[1] Bryant, 'Valves in the Veins of the Human Intestines,' *Boston Medical and Surgical Journal*, October 1888.

from these glands form the truncus intestinalis, which ends in the cisterna chyli. The lymphatics of the upper part of the duodenum join the superior pancreatic glands, and those of its lower part terminate in the pancreatico-duodenal glands.

The **nerves** of the small intestine arise from the lower thoracic spinal nerves,

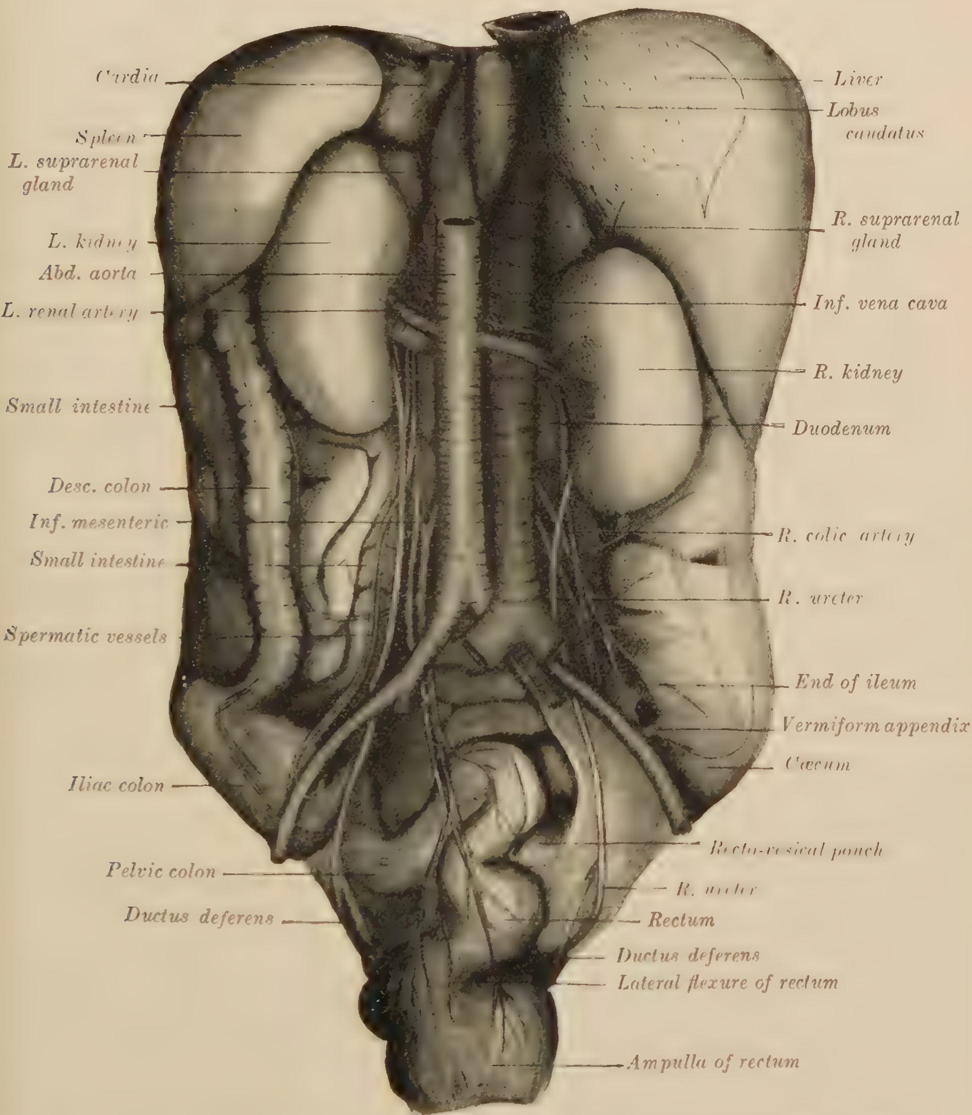


FIG. 109.—THE ABDOMINO-PELVIC VISCERA OF A MAN AGED FIFTY-ONE YEARS, VIEWED FROM BEHIND. One-third natural size. (J. Symington.)

and pass through the great splanchnics to the cœliac plexus, where their fibres form synapses with the cells of the cœliac ganglia. From the cœliac plexus, non-medullated fibres pass as the superior mesenteric plexus, with the artery of the same name, to the bowel. This plexus contains vaso-motor and vaso-dilator fibres for the blood-vessels; motor and inhibitory fibres to the muscular coat, and

sensory and secretory fibres to the mucous membrane. The vagi probably contribute to the fibres in the superior mesenteric plexus. In the wall of the intestine are two gangliated plexuses: namely—between the two layers of the muscular coat and in the submucous coat.

INTESTINUM CRASSUM.

The large intestine (*intestinum crassum*) extends from the termination of the ileum to the anus. It is divided into the *cæcum* (with the *vermiform appendix*),

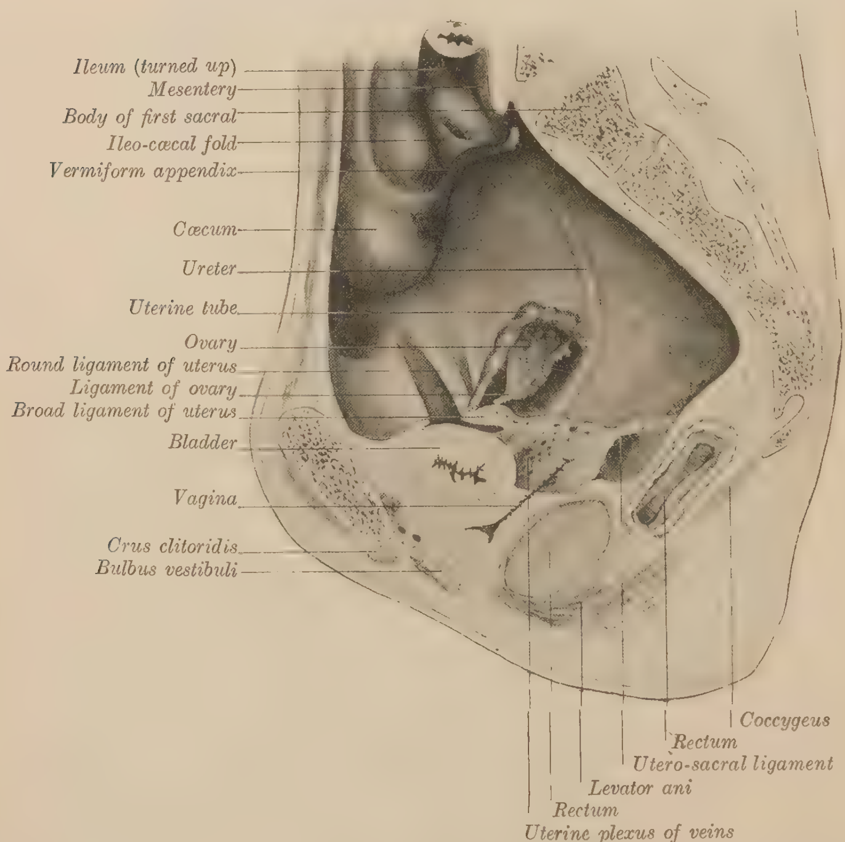


FIG. 110.—SAGITTAL SECTION OF THE PELVIS OF A FEMALE AGED TWENTY-FOUR YEARS, MADE ABOUT 12 MM. TO THE RIGHT OF THE MEDIAN PLANE. One-half natural size. (J. Symington.)

The jejuno-ileum was removed with the exception of the terminal portion of the ileum, which was divided and turned upwards. The cæcum and vermiform appendix are exposed from the median aspect.

the *colon*, and the *rectum*; and the colon is again subdivided, according to its direction or position, into five parts, called the ascending, transverse, descending, iliac, and pelvic colon.

The length of the large intestine is usually about 1·5 metres to 2 metres; being about one-fifth of the whole length of the intestinal canal. Its diameter, which for the most part greatly exceeds that of the small intestine, varies at different points and under different conditions from 2 cm. to 6 cm. As a rule, it diminishes gradually

from its commencement at the cæcum to the lower end of the pelvic colon; while the rectum tends to increase in size from above downwards, and may present at its lower end a well-marked ampulla.

POSITION AND RELATIONS OF THE DIFFERENT PARTS OF THE LARGE INTESTINE.

THE CÆCUM.—The *intestinum cæcum*, or *caput coli*, is that part of the large intestine which is situated below the ileo-colic orifice.

In many cases it is difficult, by external examination, to determine the precise position of the ileo-colic orifice and, consequently, of the upper limit of the cæcum; for the ileum does not pass transversely into the large intestine, but runs obliquely upwards, and the adjacent walls of the ileum and cæcum are closely united for some distance below the orifice (see fig. 111). At the junction of the median walls of the ileum and ascending colon, where the mesentery is attached, an invagination of both walls occurs to form the upper valve of the orifice (see fig. 127),

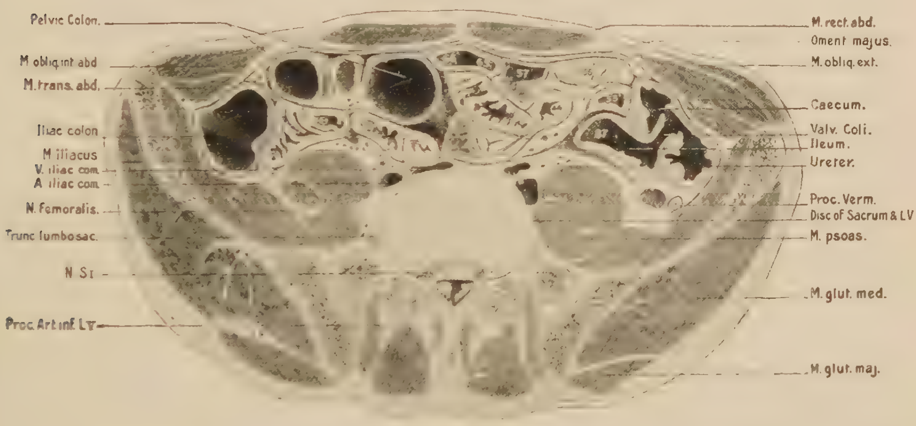


FIG. 111.—HORIZONTAL SECTION OF THE ABDOMEN OF A MAN AGED FIFTY YEARS. (P. T. Crymble.)
In the right iliac fossa the end of the ileum, the ileo-colic orifice and valvula coli, the cæcum and the vermiform appendix are exposed.

but it is frequently necessary to remove the peritoneum and some fat and blood-vessels before the furrow is seen. By the reflexion of the anterior wall of the cæcum and adjacent portion of the ascending colon, the orifice is exposed and the limits of the cæcum displayed.

The cæcum is normally situated in the right iliac fossa, above the outer half of the inguinal ligament. Behind, and laterally (see fig. 111), is the iliacus muscle, covered by the parietal peritoneum. Between this peritoneum and the muscle, there are extra-peritoneal fat, the fascia covering the muscle, the lateral cutaneous and, sometimes, the genito-femoral nerve. Not infrequently the vermiform appendix lies in the retro-cæcal peritoneal pouch. The anterior surface of the cæcum is normally in contact with the parietal peritoneum lining the anterior abdominal wall. The median or left side of the cæcum is related to the terminal part of the ileum and some convolutions of the small intestine. The peritoneum covers it in front, below, and at the sides; behind, the peritoneum is usually reflected from the bowel, about the level of the ileo-colic opening, so that the whole of the posterior surface is covered. Occasionally, this reflection occurs a little below the level of the valve, but more frequently the retro-cæcal pouch extends upwards for some distance on the back of the ascending colon. There is no meso-cæcum.

In order to appreciate the significance of the variations in the position and form of the cæcum, it is necessary to study the changes it undergoes, from early fetal until adult life, or even old age. The cæcum appears about the end of the first month as an outgrowth from the caudal limb of a U-shaped loop of the intestine. This loop protrudes into the umbilical cord, but is gradually drawn into the abdomen before the umbilicus closes. The proximal portion of the loop grows more rapidly than its distal, and the convoluted small intestine thus formed comes to lie in front of the cæcum. A rotation of the intestinal loop is produced by the unequal growth of its two limbs, by which the cæcum is carried upwards and forwards towards the liver and in front of the small intestine. As this rotation continues, the cæcum passes downwards and to the right, below the liver, and in front of the duodenum and the lower part of the right kidney; while the terminal portion of the ileum is moved downwards and to the right, so that the cæcum gradually comes into contact with the right posterior abdominal wall. The cæcum then descends into the iliac fossa in front of the ilio-psoas, and may even turn inwards across this muscle into the true pelvis. This pelvic site is acquired most frequently in old age, but it may occur even in childhood. I have a specimen, in a boy three years old, where the cæcum crossed over the bladder to the left of the median line, and the ileo-colic orifice was cut across in making a median section of the trunk. The cæcum may be arrested in any part of its course, and it may be included along with the jejunum and ileum in the mesentery.

At first the diverticulum from the intestine shows no differentiation into the cæcum and the vermiform appendix, and, according to Broedel,[1] this differentiation occurs in two distinct stages—a *primary* beginning at about the eighth week of embryonic life, and a *secondary* making its appearance at birth (p. 71). During fetal life, the distal portion grows slowly and uniformly, while the proximal part expands into a cone, to the apex of which the appendix is attached. At birth, the longitudinal fibres appear to be spread over the entire circumference of the cæcum; but these fibres soon begin to be arranged in three longitudinal bands, and the intervening portions tend to become sacculated.

The cæcum may be prolonged downwards in the adult as a conical process, with its axis approximately parallel to that of the ascending colon. This condition, however, is very rare. Toldt[2] has shown that even in early fetal life, the junction of the ileum with the large intestine is marked by a kink, so that the cæcum is bent at a right or even an acute angle to the ascending colon. The cæcum also tends to become curved, with the convexity pointing downwards and to the right, so that the apex of the cæcum comes to lie behind and to the left of the basal portion. After birth, the longitudinal bands and the sacculations tend to become distinct. The bands unite at the root of the appendix, and from their position on the cæcum are named anterior, postero-lateral, and postero-median. The areas between these bands are antero-lateral, antero-median, and posterior; of these, the antero-lateral is usually the largest, most distinctly sacculated, and forms the lowest part, or apparent apex, of the cæcum. The large size and the dependent position of the antero-lateral area are due to the direction of the cæcum, and to this area being less supported than the other two, so that it yields more readily to internal pressure. Occasionally, the antero-internal area is as large as the antero-external, and if they are both distended, the cæcum may present a bilobed appearance—more rarely, the antero-internal may be the larger—and the anterior band lies near the lateral aspect. Parsons[3] has drawn attention to the fact that, while the greater part of the cæcum may acquire a tubular form, that near the apex remains conical. Such specimens are due to partial distension of the cæcum, the conical portion remaining contracted, as is shown by its thicker walls and folded mucous membrane, while the proximal part has thin smooth walls. This division of the cæcum into two parts appears to correspond to the two-lobed form of Delmar.[4] In what is usually described as the common type, the whole cæcum forms a single dilated sac, with the appendix attached to its inner and posterior aspect a little below the ileo-colic orifice. Treves[5] described this type as occuring in 90 out of 100 cases; while Parsons met with it in only 10 out of 70 specimens. As is the case with other hollow muscular organs, the size and appearance of the cæcum are largely dependent upon the state of its muscular coat, whether contracted or relaxed. The frequency with which the saccular distended form is estimated to occur may be due in some cases to the cæcum having been examined after being blown up with air and then dried. In formal hardened subjects, in which the cæcum is examined *in situ*, the conical contracted type is not so infrequent as various observers allege. A fairly distended cæcum is about 6 cm. long and 7 cm. broad; a pretty well contracted one measures about 3·5 cm. in length and 2·5 cm. in breadth: distension, therefore, tends to increase its breadth more than its length.

[1] Kelly, *The Vermiform Appendix and its Diseases*, 1905.
[2] 'Die Formbildung des menschlichen Blinddarmes und die Valvula coli,' *Sitzungsberichte d. k. Akadamie d. Wissenschaften*, Wien, Bd. ciii., 1894.
[3] 'On the Form of the Cæcum,' *Jour. Anat. and Phys.*, vol. xlii.
[4] 'Sur la forme du cæcum,' *Bibliographie anatomique*, Supplement, 1906.
[5] *The Anatomy of the Intestinal Canal and Peritoneum in Man*, 1885.

The **processus vermiformis** (*vermiform appendix*) is a narrow tubular diverticulum of the intestine, which is attached to the true apex of the cæcum and terminates in a free blunt extremity. Its origin is usually from the posterior and median aspect of the cæcum, a little below the ileo-colic orifice: this position being acquired, as already explained, by the unequal growth or distension of the walls of the primitive conical cæcum.

The width of the appendix is about 6 mm., and its average length 9·2 cm. (Berry); but, while its diameter is fairly constant, its length is very variable. Berry [1] found it 3·1 cm. in two out of 100 cases. Fawcett [2] has reported its absence in two cases, and Piquard [3] in one. Numerous cases of long appendices have been recorded: according to Broedel,[4] the longest, 33 cm., by F. Grauer.

The position of the appendix is very variable, but most frequently it is bent or coiled up behind the upper part of the cæcum. It may, however, be comparatively straight, and point in almost any direction; the relative frequency of its direction being, according to Broedel,[5] as follows: (1) Into pelvis, (2) along iliac vessels, (3) to promontory of sacrum, (4) behind cæcum, (5) under ileum, (6) lateral to cæcum, (7) into iliac fossa, (8) amongst coils of small intestine, (9) median to cæcum over ileum. It usually has a peritoneal fold—the meso-appendix—containing its vessels and nerves, which is attached to about half the length of the appendix, its distal portion being quite free and entirely surrounded by peritoneum. The proximal part of the appendix is more or less curved owing to the shortness of its mesentery. When the appendix passes upwards behind the cæcum and ascending colon, it is usually devoid of a mesentery, so that it is fixed in position. It may occupy the anterior wall of a long retro-colic pouch, be covered in front by peritoneum, and attached to connective tissue posteriorly, or it may be entirely destitute of any peritoneal covering. The ascending type of appendix is considered to be due to an early attachment of the ascending colon to the posterior abdominal wall.

In the majority of cases, the vermiform appendix possesses a small lumen throughout its entire extent, but the cavity exhibits a distinct tendency to undergo obliteration—independent of any inflammatory condition. This process advances from the tip, is an involution of the organ, and demonstrates its retrogressive character. Out of 400 cases examined by Ribbert,[6] 99, or nearly 25 per cent., had the lumen of the appendix more or less obliterated. In 50 per cent. of the obliterated cases its distal fourth only, and in 3 per cent. the whole process was closed, while the remainder showed intermediate stages. This tendency to obliteration increased with age.

The great majority of mammals possess a cæcum, but it varies greatly in its development; as a rule, it is very large in the herbivora and small in the carnivora. In various mammals, the cæcal diverticulum becomes differentiated into a proximal portion—the cæcum proper—and a smaller distal portion—the vermiform appendix. This differentiation into two parts is as well marked in all the anthropoid apes (gibbon, orang, chimpanzee, and gorilla) as in man; but in the other primates, a distinct appendix is absent, the cæcum either ending in a blunt, rounded extremity, or being pointed and thus showing a tendency towards the formation of an appendix, except in some lemurs where it is very clearly differentiated from the cæcum.

Various peritoneal folds and fossæ occur in the region of the cæcum, vermiform appendix, end of ileum, and commencement of ascending colon. They vary in number, and still more in degree of development, but the following are fairly constant:—

The **ileo-colic fold** (superior ileo-cæcal fold of Treves) is situated between the ileum and the ascending colon. It springs from the ventral surface of the mesentery

[1] 'The Anatomy of the Vermiform Appendix,' *Anat. Anzeiger*, Bd. x., July 1895.
[2] *Proc. Anat. Soc. of Great Britain and Ireland*, February 1900; *Jour. Anat. and Phys.*, vol. xxxiv.
[3] *Bulletin de la Société anat. de Paris*, 1900.
[4] Kelly, '*The Vermiform Appendix*, p. 136.
[5] *Ibid.*, p. 126.
[6] 'Beiträge zur normalen und pathologischen Anatomie des Wurmfortsatzes,' *Virchow's Arch.*, Bd. cxxxii., 1893.

and passes, in front of the termination of the ileum, to the adjacent part of the colon, sometimes extending downwards, slightly on to the front of the cæcum. Its free border is concave, and directed downwards and inwards. This fold contains some of the anterior branches of the ileo-colic artery, lymphatic vessels, and frequently several small lymphatic glands. Behind this fold is an ileo-colic (superior ileo-cæcal of Treves) fossa of varying depth. The largest Treves met with in a hundred subjects admitted the thumb up to the root of the nail.

The **ileo-cæcal fold** (fig. 110) (inferior ileo-cæcal fold of Treves), usually much larger than the ileo-colic, is attached above to the anti-mesenteric or free border of the ileum for from 2 cm. to 3 cm., and on the right side to the median aspect of the cæcum, while its lower border is free. This fold was described as 'bloodless' by Treves, as compared with the ileo-colic which is developed by the arteries passing to the front of the cæcum. It contains a few fine blood-vessels, and forms the anterior boundary of the ileo-cæcal fossa, which will sometimes admit two or three fingers. This fold is the primitive mesentery of the cæcum, and is formed between the cæcum and the adjacent portion of the ileum as the cæcal pouch grows out. The fossa behind this fold—ileo-cæcal—(inferior ileo-colic of Treves) is nearly always present, and will generally admit two fingers up to the second joint (Treves). The opening of the fossa is below and to the left.

Retro-cæcal and retro-colic fossæ.—These are often absent, and, when present, vary in depth, number, and position. The peritoneum covering the posterior aspect of the cæcum may be reflected on to the iliac fossa along a straight line, and then the retro-cæcal fossa is absent. In other cases, the line of reflexion is irregular, and gives rise to one or more pouches open below and having their blind extremities upwards. These recesses may be broad and shallow, or narrow and deep, and in the latter case they pass upwards behind the ascending colon, sometimes nearly as far as the hepatic flexure. They may be placed directly behind the cæcum, and towards its median and lateral aspects; the deepest recess is usually found near the median aspect.

The posterior surfaces of the cæcum and ascending colon are at first covered by peritoneum, but union subsequently occurs between this peritoneum and the parietal layer behind it. If this union takes place along two or more vertical lines, the intervening areas form one or more peritoneal pouches. These fossæ are only seen after the cæcum is turned upwards. Sometimes the vermiform appendix ascends in the anterior wall of a retro-cæcal fossa, and, should this peritoneal pouch become obliterated, the appendix lies in the connective tissue behind the cæcum and ascending colon, and is destitute of a serous covering or mesentery.

COLON.—The **ascending colon** is continuous with the cæcum at the level of the ileo-colic opening. It passes upwards and somewhat backwards towards the liver, below which organ it ends by turning forwards and to the left, this bend being termed the hepatic flexure of the colon. Its length depends on the extent to which the cæcum descends, and, should the latter remain in contact with the liver, no ascending colon is formed. On an average, it is about 12 cm. long. Starting below at the level of the ileo-colic orifice, it passes upwards, resting on the iliacus muscle, and having the transversalis abdominis muscle on its outer side. It then goes in front of the iliac crest, and ascends in the lumbar region in front of the outer part of the quadratus lumborum muscle, until it reaches the liver, near the tip of the eleventh rib. At its termination, the lower end of the kidney lies internal to it. As a rule, the part of the ascending colon, below the iliac crest, is rather longer than that above the crest. The commencement of the ascending colon is usually in contact with the anterior abdominal wall, but, after a short course, it may become overlapped by convolutions of the jejuno-ileum or a descending limb of the transverse

colon. The peritoneum normally invests it in front and at the sides, but leaves the posterior surface uncovered. Transverse folds of peritoneum are occasionally found extending from the front of the ascending colon to the lateral wall of the abdomen. It may be included with the jejuno-ileum in the common mesentery, a persistence of the fetal condition, or the retro-cæcal or ileo-cæcal pouch may extend upwards for a variable distance behind it. The vermiform appendix, with or without a peritoneal covering, is not infrequently a posterior relation.

The **transverse colon** extends across the abdomen from the hepatic flexure—which is situated on the under-surface of the right lobe of the liver, lateral to the

FIG. 112.—HORIZONTAL SECTION OF ABDOMEN OF A MAN AGED FIFTY YEARS. THE ASCENDING AND DESCENDING PARTS OF THE COLON ARE DIVIDED IN THE RIGHT AND LEFT LUMBAR REGIONS RESPECTIVELY. (P. T. Crymble.)

gall-bladder and median to the eleventh right rib—to the splenic flexure, a sharp bend on the colon placed opposite the ninth left rib, and just below the spleen. It is not uncommon to find the two ends of the transverse colon lower than the points just mentioned; but their relative position is usually maintained, the splenic flexure being higher up and farther back than the hepatic. Between these two points, the transverse colon generally forms a loop directed downwards and forwards; but its course across the abdomen is very variable, as can readily be appreciated when we realise that its principal relations are movable hollow viscera, its peritoneal connexions such as permit of free mobility, and that its length varies from less than 25 cm. to more than 50 cm. It frequently crosses the median plane at the level of the umbilicus, but it may do so as high as the ensiform cartilage, or as low as the pubes.

Above, the transverse colon is in contact with the under-surface of the liver, the gall-bladder, the great curvature of the stomach, and the lower end of the spleen. It is covered in front by the great omentum. On the right side, some coils of the small intestine may lie anterior to it, while near its termination it is often behind the stomach. From the hepatic flexure, it passes forwards and inwards, over the lower end of the right kidney and the second part of the duodenum, and a small piece of the head of the pancreas; and it is united to these structures by areolar tissue, or attached by a short peritoneal fold. In the rest of its course it has behind it some of the convolutions of the jejunum and ileum. The two layers of the *transverse meso-colon* are attached opposite its upper or mesenteric

tænia, and, after investing the colon, they join at the omental tænia, to become continuous with the great omentum (fig. 125). The part of the transverse mesocolon, which is often found in front of the duodenum, is formed entirely by the great sac, while that to the left of the duodenum is derived from both great and small sacs. The terminal few inches of the transverse colon often go almost directly backwards.

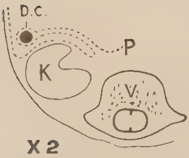


Fig. 113.—Horizontal section through the abdomen of a fetus 8 cm. long. (J. Symington.)

D.C., descending colon; P, peritoneum; K, left kidney; V, body of vertebra.

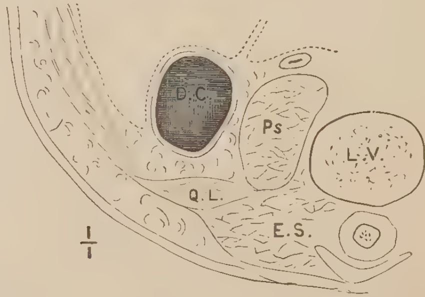


Fig. 114.—Horizontal section through abdomen of a nine-months' fetus. (J. Symington.)

D.C., descending colon; Ps, psoas muscle; Q.L., quadratus lumborum; E.S., erector spinæ; L.V., lumbar vetrebra.

The **descending colon** is continuous with the left extremity of the transverse colon at a sudden bend, named the *splenic flexure*, which is higher up and farther back than the hepatic flexure. At this bend, there is found a fold of peritoneum—the costo-colic or phrenico-colic ligament—which stretches with a lunated free border to the colon from the diaphragm, opposite the tenth or eleventh rib. As

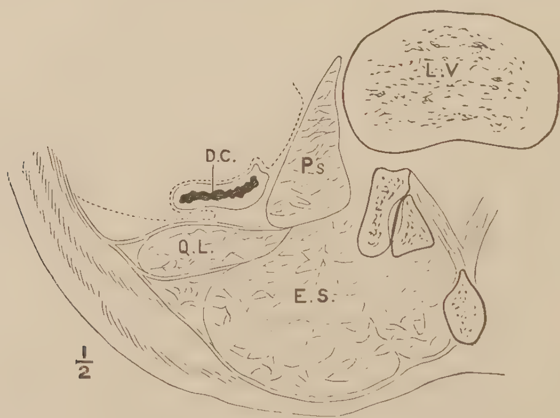


Fig. 115.—Horizontal section through the abdomen of an adult male. (J. Symington.)

L.V., lumbar vertebra; Ps, psoas muscle; Q.L., quadratus lumborum muscle; E.S., erector spinæ; D.C., descending colon.

was pointed out by Haller, it supports the spleen, although unconnected with that organ, and may be termed 'sustentaculum lienis.' From the splenic flexure, the colon descends in contact with the outer border of the lower half of the left kidney.

At the lower end of the kidney it may turn inwards a little, and then descend near the outer border of the psoas muscle to the iliac fossa, where it joins the iliac

colon; or it may go straight down, near the outer border of the quadratus lumborum, leaving an interval between it and the psoas muscle, which is occupied by some convolutions of the jejunum (see fig. 83). The descending colon is often found empty and contracted, and covered in front by small intestine. It is about 10 cm. long, but may be shorter owing to a low position of the splenic flexure.

In a young fetus (see fig. 113), the descending colon has a relatively long meso-colon, which is attached to the abdominal wall internal to the kidney, then passing outwards in front of that organ it joins the colon. This meso-colon is obliterated before birth (see fig. 114), probably by a blending of its posterior layer with the peritoneum in front of the kidney. After fetal life, the descending colon is generally covered by peritoneum on its anterior and outer surfaces; the posterior and inner surfaces being uncovered.

Occasionally, especially when the colon is empty, the peritoneum lies behind the outer part of the posterior surface (see fig. 115); but the existence of a distinct *descending meso-colon* is rare.

The **iliac colon** begins at the iliac crest, and passes downwards and inwards in the iliac fossa to the brim of the pelvis, where it joins the pelvic colon. Sometimes (see fig. 85) it occupies the outer and lower part of the iliac fossa, first descending internal to the iliac crest and then turning inwards near the upper border of the inguinal ligament. In these cases, it lies in contact with the anterior abdominal wall, and the coils of the jejuno-ileum are in relation with its upper and inner borders. On the other hand, the iliac colon may descend along the outer border of the psoas, and then turn inwards over this muscle, some little distance above the inguinal ligament. Under these circumstances, the small intestine separates it from the anterior abdominal wall and occupies the outer and lower part of the iliac fossa. This latter position is usually associated with an empty and a contracted iliac colon, and it is probable that, on distension, the iliac colon would push the small intestine aside and occupy the outer and lower part of the fossa. Intermediate conditions are met with in which, on reflecting the anterior abdominal wall, part of the iliac colon is visible, the remainder being concealed by the small intestine. The iliac colon is about 12 cm. long. In the greater part of its extent it rests on the iliacus muscle, but its terminal portion is in front of the psoas muscle. There is, as a rule, no iliac meso-colon—the peritoneum covering it only in front and at the sides; and the posterior surface is connected by cellular tissue with the iliac fascia. Should a mesentery be present, it is a short one and limited to the terminal portion.

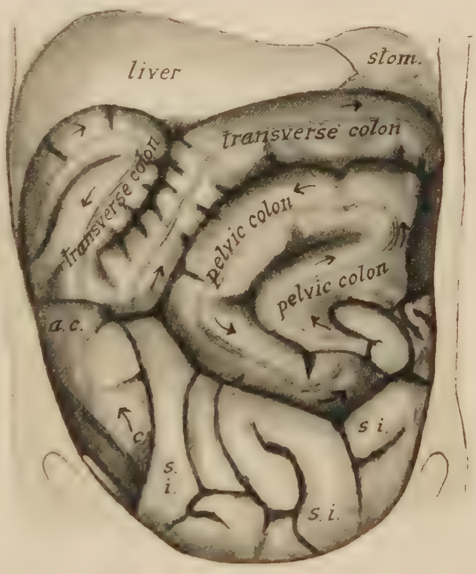


FIG. 116.—SPECIMEN OF THE PELVIC COLON PROJECTING UPWARDS INTO THE ABDOMEN AND FORMING A LARGE LOOP LYING AGAINST THE ANTERIOR ABDOMINAL WALL. (J. Symington.)

c., cæcum; *a.c.*, ascending colon; *s.i.*, small intestine.

The **pelvic colon** [1] extends from the median border of the left psoas muscle to the front of the third sacral vertebra. It is distinguished from the iliac colon and the rectum, between which it intervenes, by having a mesentery—the pelvic mesocolon. The important variations in its length and position are associated with the condition of this mesentery. If this is short, the pelvic colon passes backwards and downwards on the side wall of the pelvis, and gradually inclines inwards to end near the median plane in front of the third sacral vertebra. Usually, however,

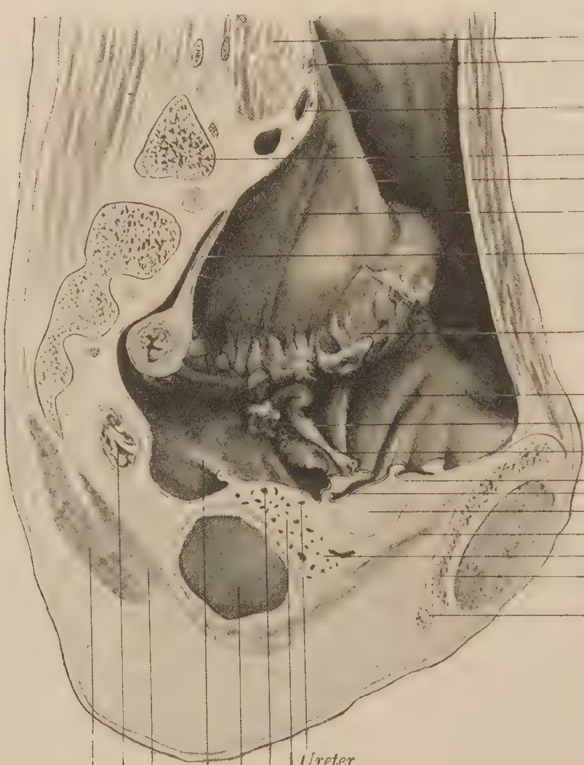


Fig. 117.—Sagittal section of the pelvis of a female aged twenty-six years, made about 2·5 cm. to the left of the median plane. One-half natural size. (J. Symington.)

Coils of the jejuno-ileum were removed. The pelvic colon is exposed lying against the wall of the pelvis.

the mesentery is long, and the pelvic colon forms a freely movable U-shaped loop, which may either hang down into the pelvis or, more rarely, project upwards into the abdomen (see fig. 116). When dipping down into the male pelvis, it may come into contact with the bladder, rectum, and coils of small intestine. In the female, it is usually in relation with the left ovary and uterine tube, but it may extend across the pelvis to the corresponding structures on the right side. When projecting

[1] *The colon descendens* of the *B.N.A.* includes the descending and iliac colons, as described above, and its *colon sigmoidum* is equivalent to our pelvic colon, except that the terminal portion of the pelvic colon is included under the *rectum* in the *B.N.A.*

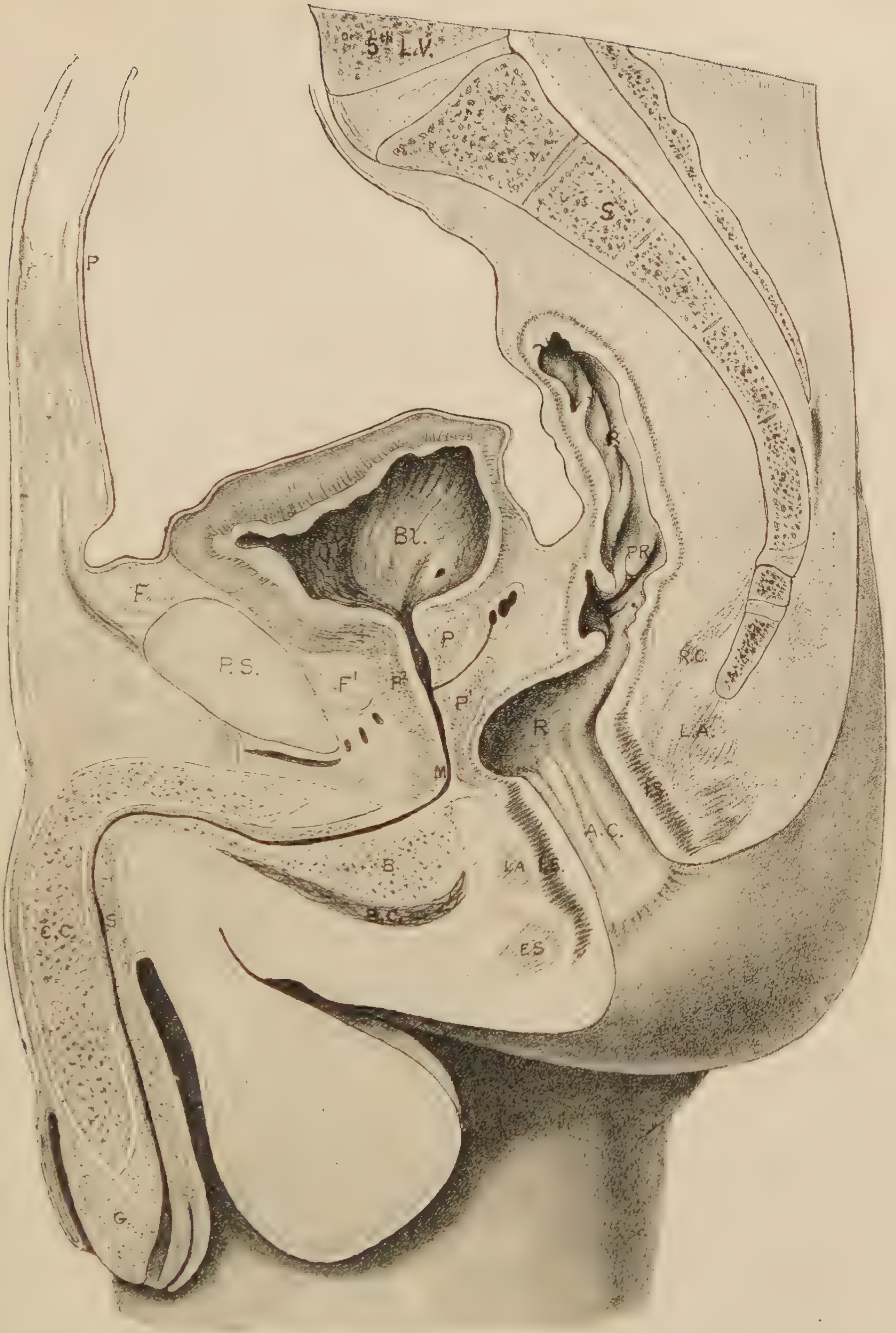


FIG. 118.—MEDIAN SECTION OF THE PELVIS AND ITS VISCERA IN AN ADULT MALE. Three-fifths natural size. (J. Symington.)

The bladder contained about 3 oz. of urine, and there were some fæces in the lower part of the rectum. 5th L.V., body of fifth lumbar vertebra; S, on body of second sacral vertebra; P.S., pubic symphysis; R.R., rectum; P.R., a plica transversalis recti; A.C., anal canal, with its longitudinal folds of mucous membrane—the columns of Morgagni. The tissues between the anal canal and the coccyx constitute the ano-coccygeal body. I.S., internal sphincter; E.S., external sphincter; L.A., levator ani; R.C., recto-coccygeus muscle; Bl., bladder; P, P¹, P², prostate gland; P, its middle lobe, between P and P¹, the common ejaculatory duct; M, membranous part of urethra; S., cavernous part of urethra; C.C., corpus cavernosum penis; G., glans penis; B., bulb of corpus cavernosum urethræ; B.C., bulbo-cavernosus muscle; F., supra-pubic pad of fat; F¹, retro-pubic pad; *p*, peritoneum.

into the abdomen, it often reaches as high as the umbilicus, and Corning[1] figures a specimen where it was in contact with both the liver and the stomach, and measured 1 metre in length.

The attachment of the pelvic meso-colon to the body-wall begins at the psoas muscle; it then crosses the iliac vessels near the bifurcation of the common iliac, and, turning somewhat abruptly downwards and inwards, is situated in front of the upper two pieces of the sacrum. The meso-colon is short towards its two

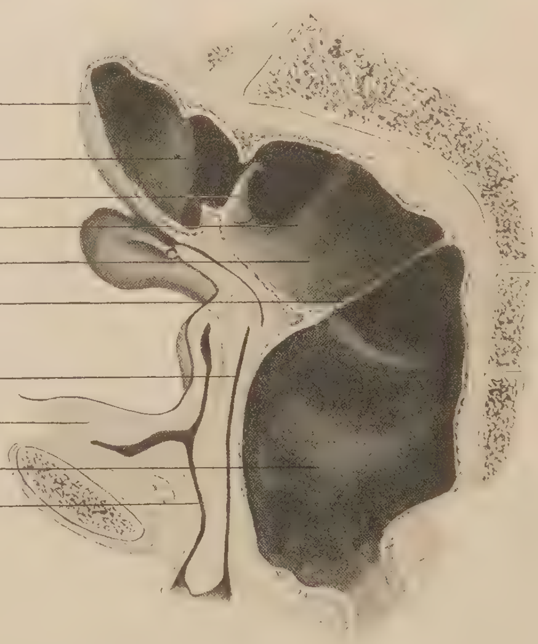


FIG. 119.—MEDIAN SECTION OF THE PELVIS OF AN ADULT FEMALE. One-half natural size. (J. Symington.) The rectum was distended with fæces.

extremities, but the middle portion often measures 8 cm. to 10 cm. in length, and thus permits the pelvic colon to form a long U-shaped loop. Occasionally, the base of this portion of the pelvic meso-colon is quite narrow, the two ends of the loop being scarcely an inch apart. When the pelvic meso-colon is thrown upwards, a funnel-shaped recess is often found behind its root, which extends upwards for a variable distance along the course of the left ureter.

The pelvic colon is relatively much longer, in relation to the other portions of the large intestine, during fetal life than in the adult. Treves found that in the full-time fetus, the pelvic colon was 10 inches long, and the rest of the large intestine 1 foot. At this period, the pelvic colon lies almost entirely in the abdomen, and often reaches over into the right iliac fossa. For several months after birth, the pelvic colon diminishes in length, while the rest of the colon grows, so that the adult proportions are soon attained.

The **rectum** begins in front of the third sacral vertebra, where it joins the pelvic colon, and terminates on the pelvic floor by passing into the anal canal. It first inclines downwards and somewhat backwards, and then gradually curves forwards and downwards; in addition to the main sagittal curve, it frequently exhibits several lateral bends—especially when contracted. Its average length is about

[1] *Lehrbuch der topographischen Anatomie*, Zweite Auflage, Wiesbaden, 1909, fig. 353.

12 cm. to 15 cm., but distension tends to increase its length and straighten its course. When empty and contracted, it may have a diameter of 2 cm. (see fig. 228). On distension it has a saccular form, and increases in size from above downwards; the lowest sacculation, called the ampulla, may attain a diameter of 12 cm. It has no mesentery, and, as the pelvic colon is provided with one, the place where the bowel loses its mesentery is considered to mark the colo-rectal junction.

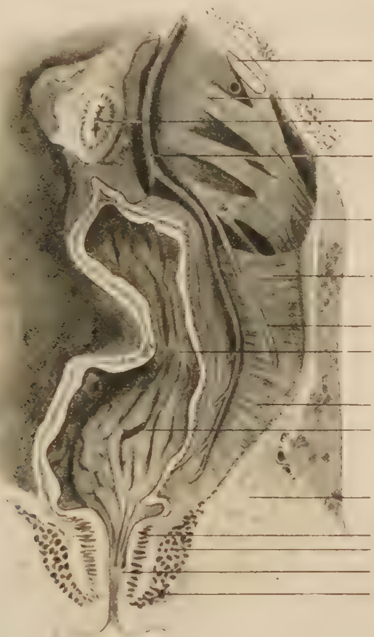


FIG. 120.—RECTUM EXPOSED FROM THE FRONT AND OPENED BY A LONGITUDINAL INCISION. ANAL CANAL DIVIDED TRANSVERSELY. One-half natural size. (J. Symington.)

A sphincter muscle and a fold of mucous membrane have also been described as indicating the point of union.

The posterior surface of the rectum rests, from above downwards, on the lower part of the sacrum, the coccyx, and the posterior portion of the pelvic floor. Occasionally, there is a considerable amount of fat between the rectum and the sacrum. The relations of the anterior surface vary, according to the sexes and the state of the bladder and rectum. If the male bladder is full of urine, and the rectum contains a quantity of fæces, these two organs are in close contact, and the recto-vesical pouch is reduced to a narrow cleft; when these organs are empty, a large space is formed, which is occupied by the convolutions of the jejuno-ileum and the pelvic colon. Below the bottom of the recto-vesical pouch, the anterior surface of the rectum lies in relation to the lower parts of the ductus deferentes and of the seminal vesicles, a small area of the bladder, and the prostate gland. Just below the apex of the prostate, the anterior wall of the rectum turns downwards and backwards; but occasionally a pouch is formed in this situation, directed towards the membranous part of the urethra (see fig. 118). On each side of the upper part of the rectum there is a para-rectal pouch of peritoneum, and, behind and below this, some para-rectal connective tissue. The sides of a distended rectum may be in

close contact with the ureters and the outer part of the seminal vesicles. In the female, the pouch of Douglas may be empty, and the rectum be closely approximated to the uterus and upper end of the vagina (see fig. 119), or the pouch may be occupied by intestines. Below the peritoneum, the anterior wall of the rectum is closely applied to the vagina.

The rectum is surrounded by a rather loose and fatty mass of connective tissue,

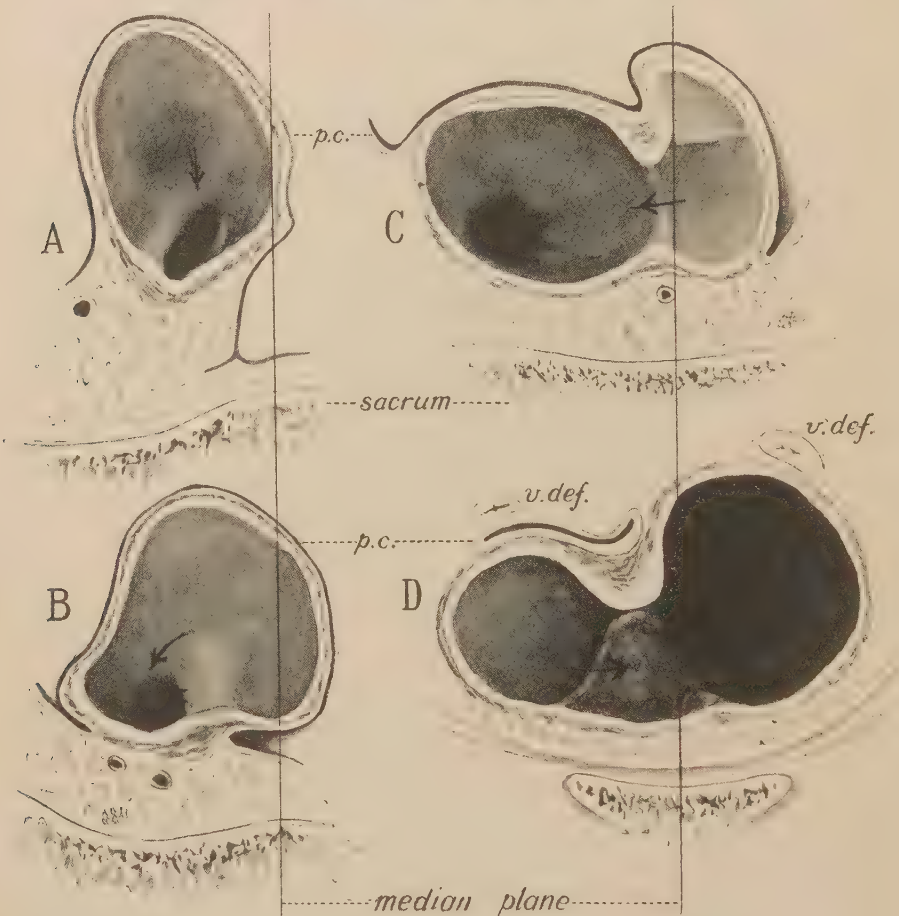


Fig. 121.—From a series of horizontal sections of the pelvis of a man aged fifty years. Natural size. (J. Symington.)

The position of the sections is shown in fig. 87. A is from the upper surface of slab 10 on fig. 87; B, ditto of slab 11; C, ditto of slab 12; and D, ditto of slab 13. The pelvic colon and the rectum are divided as they lie in front of the sacrum and coccyx, and the series of sections shows the curved course and alternate dilatations and constrictions of these parts of the intestine when moderately distended. A is through the terminal portion of the pelvic colon; B, C, and D, through the rectum. D is opposite the lower end of the recto-vesical pouch of peritoneum; *v.def.*, ductus deferens; *p.c.*, peritoneal cavity.

external to which is a more compact layer separating it from the sacrum behind and the genital organs in front.

The **anal canal** [1] (*pars analis recti*) is the terminal portion of the alimentary tube, which is surrounded by the sphincters of the anus. Its lumen forms a median slit in the pelvic floor, opening above into the rectum and below into the cleft, between

[1] J. Symington, 'The Rectum and Anus,' *Jour Anat. and Phys.*, vol. xxiii., 1888; and 'Further Observations on the Rectum and Anal Canal,' *ibid.*, vol. xlvi., 1912.

the two buttocks. The canal is directed downwards and backwards, and measures about 25 mm. in length when the rectum is empty, but is somewhat shorter when the rectum is distended. Its antero-posterior extent is from 10 mm. to 15 mm., and in both sexes it begins 2 cm. to 3 cm. in front of the tip of the coccyx. The mass of tissue between the two forms a part of the pelvic floor and is known as the ano-coccygeal body. External to its muscular wall, is the fat of the ischio-rectal

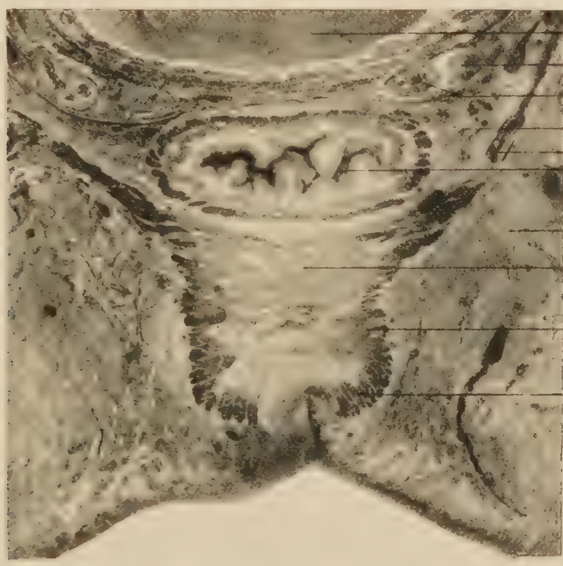


FIG. 122.—OBLIQUE CORONAL SECTION OF RECTUM, ETC., IN A MAN AGED SEVENTY-FOUR YEARS. Natural size. From a photograph. (J. Symington.)

The rectum is divided where it lies on the pelvic floor, in front of the coccyx and behind the anal canal. The wall of the rectum is seen to be composed of a folded mucous membrane, a submucous coat (light in colour), and of two layers of muscular fibres, of which the outer and longitudinal layer appears darker and better developed than the inner circular layer. At this level there is no serous coat. The bladder was considerably distended and the seminal vesicles partially atrophied.

fossa. Its anterior relations vary according to the sex. In the male, the bulb of the penis is rather more than 1 cm. in front of it; while in the female it is separated from the lower part of the vagina and the pudendal opening by the perineal body.

APPEARANCE AND NAKED-EYE STRUCTURE OF THE LARGE INTESTINE.

The large intestine has four coats, like those of the stomach and small intestine: namely—the serous, muscular, submucous, and mucous.

The **serous** coat is for the most part similar to that of the small intestine, except that, along the colon, it is prolonged into numerous projections, enclosing fat, which are called *appendices epiploicæ*. These appendices vary greatly in size, and in stout individuals may be 4 cm. to 5 cm. long, give off a number of secondary processes, and be loaded with fat. On the vermiform appendix, the serous membrane is smooth and closely adherent to the subjacent muscular fibres; but two rows of appendices epiploicæ, one on each side, project from its mesentery close to the appendix. Occasionally, some rudimentary appendices epiploicæ are found on the free surface of the vermiform appendix. The epiploic appendages are found along the whole of the colon, and are usually best marked on the transverse colon and the pelvic colon. They are seldom conspicuous on the cæcum, and, on the

ascending and descending colon, are mainly attached to the median and lateral surfaces, while on the transverse colon, they spring almost entirely from its posterior surface, being attached between the two longitudinal muscular bands, termed tænia meso-colica and tænia libera, and, when well developed, also from the adjacent part of the transverse colon. On the pelvic colon, they often form two somewhat irregular rows, situated on each side of the bowel; they gradually become smaller in size and fewer in number towards the end of the pelvic colon, and they are absent from the rectum.

The **muscular coat** consists of external longitudinal and internal circular fibres. On the cæcum and the ascending, transverse, and descending colons, the longitudinal fibres are arranged in three bundles, known as tænæ coli, the intervening

FIG. 123.—OBLIQUE CORONAL SECTION OF THE TERMINATION OF THE RECTUM, THE ANAL CANAL, ETC., IN A MAN AGED SEVENTY-FOUR YEARS. Natural size. From a photograph. (J. Symington.)

The section is about 2·5 cm. in front of that shown in fig. 122. The mucous membrane of the anal canal is somewhat redundant, and the buttocks were separated from one another before the section was made.

parts of the wall being almost destitute of longitudinal fibres. These three bundles unite at the attachment of the vermiform appendix to the cæcum. From this point, an anterior tænia, or *tœnia libera*, passes on to the front of the cæcum, and then ascends in a similar position on the ascending colon. At the hepatic flexure, owing to a rotation of the transverse colon on its long axis, it turns on to the posterior surface of the transverse colon, regaining its former position at the splenic flexure, so that it descends on the front of the descending colon. The other two bands are termed postero-lateral and postero-median. The postero-median ascends from the vermiform appendix behind the termination of the ileum, at the upper border of which it bridges over a distinct inflexion of the intestinal wall which forms the upper lip of the ileo-colic valve. On the transverse colon, this tænia is on the upper border at the attachment of the transverse meso-colon, hence it is called *tœnia meso-colica*. In the descending colon, it again becomes postero-median in position. The postero-lateral tænia occupies this position on both the ascending and descending colons, but is in front of the transverse colon where the great omentum is attached (*tœnia omentalis*).

In the empty contracted condition of the colon, these tæniæ are about 5 mm. broad and 1 mm. thick; but, as the bowel is distended, they become broader and

thinner. Measured from end to end, these three bands are shorter than the intervening parts of the tube, and the latter are thus thrown into sacculi, accordingly, when the bands are removed, the sacculi are entirely effaced, and the colon, elongated considerably, assumes the cylindrical form. The transverse constrictions seen on the exterior of the intestine, between the sacculi, appear on the inside as ridges (*plicæ semilunares coli*), and the sacculi as recesses (*haustra coli*).

The longitudinal fibres form a fairly uniform layer, about 0·2 mm. in thickness, in the appendix. In the iliac colon, the anterior and the postero-lateral tæniæ of the descending colon tend to run together, forming an anterior or free tænia. These two tæniæ, with two rows of sacculi, are found on the pelvic colon, and the longitudinal fibres are continued down the front and back of the upper part of the rectum, but, towards its lower end, they are found all round the rectum (see fig. 122), and are then prolonged into the wall of the anal canal external to the internal sphincter of the anus.

FIG. 124.—OBLIQUE CORONAL SECTION OF ANAL CANAL, ETC., IN A YOUNG ADULT MALE. Natural size. (J. Symington.)

B., cavity of bladder; V.D., ductus deferens; S.V., seminal vesicle: R. rectum; A.C., anal canal: L.A., levator ani; I.S., internal sphincter of anus; E.S., external sphincter of anus.

The circular muscular fibres have the same general arrangement as in the small intestine, but they are thicker opposite the intervals between the sacculi of the colon and the transverse folds of the rectum than over the surface generally. At the lower end of the rectum, the circular fibres are continuous with the internal sphincter of the anus. A pair of small bands of plain muscular tissue, which arise from the front of the second and third coccygeal vertebræ, and are also connected with the pelvic fascia, pass with a slight downward inclination to the posterior part of the anal canal (see fig. 118), and become intermingled with its longitudinal fibres. They are known as the recto-coccygeal muscles. The submucous or areolar coat resembles in all respects that of the small intestine.

The **mucous membrane** differs from that of the small intestine in being destitute of villi. Viewed with a lens, its surface is seen to be marked all over by the orifices of numerous tubular glands (*crypts of Lieberkühn*, fig. 104), resembling those of the small intestine, but longer and more numerous, and further distinguished from them by the large number of mucous cells which they contain.

Scattered over the whole large intestine, *lymphoid nodules* are found—similar to the solitary glands of the small intestine. They are most numerous in the cæcum and its vermiform appendix, being placed closely all over the latter.

When the large intestine is empty and firmly contracted, its mucous membrane is thrown into numerous folds: sometimes definitely longitudinal in direction, more

frequently in an irregular manner. As the intestine begins to distend, its walls yield unequally to the internal pressure, and saccular dilatations are formed, the lining of which is smooth, while in other situations the folds of mucous membrane run in various directions. As the distension progresses, most of the folds disappear, but a few remain as transverse or oblique crescentic shelves, projecting towards the lumen from about one-half of the circumference of the wall. Such crescentic folds may be found in any portion of the large intestine when distended, but they are usually best marked in the ascending and transverse colon and in the rectum. They usually correspond to a flexure of the bowel, and consist, in addition to the mucous and submucous coats, of some fibres of the circular muscular layer.

In the rectum, these folds (*plicæ transversales recti*) were described by J. Houston [1] as valvular; O. Kohlrausch [2] named the most prominent one, *plica transversalis*

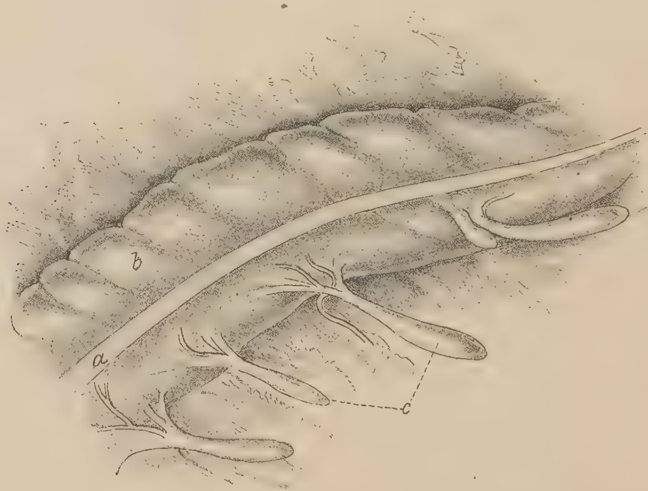


FIG. 125.—TRANSVERSE COLON, EMPTY AND CONTRACTED. (Drawn by G. C. R. Harbinson.)

The great omentum is turned upwards, and the posterior surface of the colon and transverse mesocolon exposed.

a, tænia libera; *b*, one of the saccules; *c*, appendices epiploicæ.

recti; while more recently, W. J. Otis [3] has published a detailed account of their anatomy. The most constant and best-developed fold is situated on the right side, and usually extends farther on the anterior than on the posterior wall. It is nearly opposite the reflexion of the peritoneum from the rectum on to the bladder, in the male, and on to the upper part of the vagina in the female. The distance of this fold above the verge of the anus is about 6·5 cm. (Otis), but should the rectum below this level be considerably distended, it may be increased to nearly 10 cm. Paterson [4] has proposed a division of the rectum into an upper and a lower part, this plica marking their separation.

Occasionally, a plica is found below this, and one or more above it. Otis showed that, by placing the body in the genu-pectoral position, avoiding any pressure on the front of the abdomen, and opening the anus with retractors, the rectum was distended with air and two to five plicæ exposed to view. When the rectum is removed from the body and distended, it does not form a uniform cylindrical tube,

[1] *Views of the Pelvis*, Dublin, 1829; and 'Observations on the Mucous Membrane of the Rectum,' *Dublin Hospital Reports*, vol. v., 1830.

[2] *Zur Anatomie und Physiologie der Beckenorgane*, Leipzig, 1854.

[3] *Anatomical Researches in the Human Rectum*, Leipzig, 1887.

[4] 'The Form of the Rectum,' *Jour. Anat. and Phys.*, vol. xlviii., January 1909.

but exhibits lateral and more or less regularly alternating constrictions with saccular dilatations between them. The plicæ are the reverse of the constrictions.

The mucous membrane of the rectum is thicker, redder, and more vascular than that of the colon and it moves more freely upon the muscular coat.

Orifice of the appendix.—In the cæcum, two orifices are seen: namely—those of the vermiform appendix and ileum. Towards the true apex of the cæcum—especially when conical—the mucous membrane may be thrown into a number of more or less concentric folds, and one, two, or three of those situated close to the orifice of the appendix may simulate a valve. Not infrequently, a

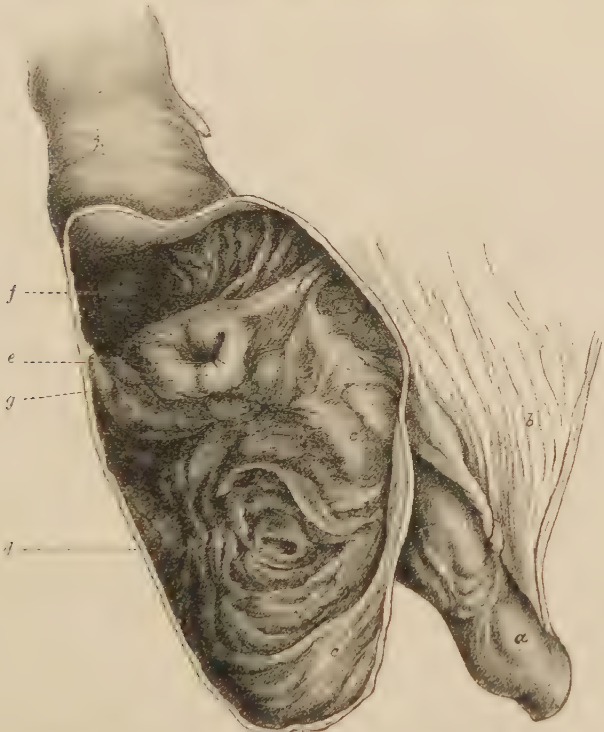


FIG. 126.—ANTERO-EXTERNAL WALL OF CÆCUM AND COMMENCEMENT OF ASCENDING COLON REMOVED TO SHOW ILEO-COLIC ORIFICE, ETC. From a specimen hardened *in situ*. (Drawn by G. C. R. Harbinson.)

a, lower end of ileum; *b*, its mesentery; *c*, *c*, cæcum; *d*, orifice of vermiform appendix; *e*, ileo-colic orifice; *f*, upper or ileo-colic segment of its valve; *g*, lower or ileo-cæcal segment; *h*, ascending colon.

semilunar fold is present at the upper part of the orifice, and is often known as Gerlach's valve. It is doubtful if any of these folds form really competent valves, preventing the contents of the cæcum passing into the appendix.

Ileo-colic orifice and valve (*valvula coli*).—This orifice appears as a transverse or oblique slit, about 1 cm. to 1·5 cm. in length, on the posterior wall of the large intestine at the junction of the cæcum and ascending colon (see fig. 126). It is guarded by a valve composed of two segments or folds, which project into the large intestine. The upper of the two folds (see fig. 127) is horizontal, and the lower oblique. At each end of the aperture, these folds coalesce, and are then prolonged as a single ridge on each side for some distance round the cavity of the intestine, forming the *fræna* or *retinacula* of the valve. When dried, after distension of the intestine, the valves appear thin with sharp edges, but in the moist condition they are thick and the borders rounded. Sometimes the lower valve does not

project forwards as far as the upper, and its free border is concave. The opposed surfaces of the valvular folds which look towards the ileum and are continuous with its mucous surface are covered like it with villi, while their other surfaces, turned towards the large intestine, are smooth and destitute of villi. In the fifth month of fetal life, both surfaces of the ileo-colic valve possess villi; but by the ninth month, the villi on the colic aspect of the valve are represented by only a few stunted processes (Langer).

Each segment of the valve consists of two layers of mucous membrane, continuous with each other along the free margin, and including between them, besides the submucous areolar tissue, a number of muscular fibres, continued from those of the ileum and of the large intestine—in fact, all the coats of the intestine except the serous. The muscular coat is thin, and consists mainly of circular fibres; but, according to Toldt, some longitudinal fibres are present, which are visible in sections examined under low powers. The function of the ileo-colic valve is to prevent the intestinal contents passing from the large into the small intestine. Its valvular action is independent of muscular contraction, as air or fluid forced into the large intestine in the cadaver does not generally find its way into the ileum. It is probable that the distension of the cæcum presses the walls of the ileum against one another much in the same way as the urine is prevented from passing from the bladder into the ureters. Some consider that distension of the cæcum stretches the frenula, and the lips of the opening are thus drawn together. The muscular fibres in the ileo-colic valves are too feebly developed in the human subject to have any appreciable sphincteric action.

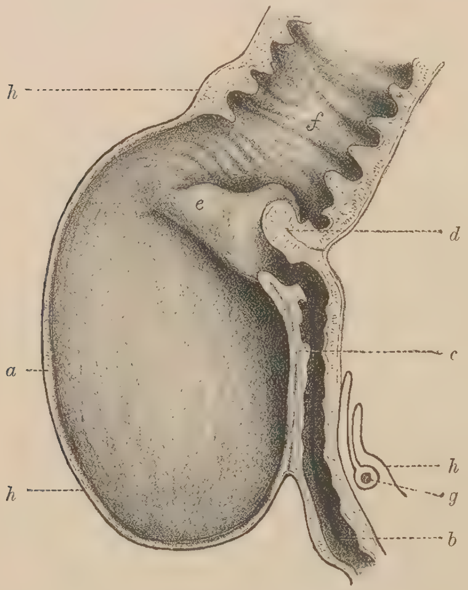


FIG. 127.—LONGITUDINAL SECTION THROUGH THE LOWER END OF THE ILEUM, THE ILEO-COLIC VALVE, THE CÆCUM, AND THE ASCENDING COLON, TO SHOW THE RELATION OF THE TERMINATION OF THE ILEUM TO THE CÆCUM. Viewed mainly from the left side. (J. Symington.)

a, antero-external wall of cæcum; *b*, cavity of ileum; *c*, lower or ileo-cæcal segment of ileo-colic valve; *d*, upper or ileo-colic segment; *e*, frenulum on right side of ileo-colic opening; *f*, ascending colon; *g*, vermiform appendix with its mesentery; *h*, *h*, *h*, peritoneum.

Debierre (*Lyon Medical*, November 1885) made a series of experiments to determine the competency of this valve by injecting, *per rectum*, air or water, with the intestines *in situ*, and he found that it permitted these to pass from the large to the small intestine in the proportion of about two out of three. When competent, however, it resisted the pressure of a column of water from 3 metres to 4 metres in height, the large intestine finally rupturing without a drop of fluid having passed through the ileo-colic orifice. He considered that, in the cases of incompetency, the cæcal segment of the valve was shorter than the colic, while in the others it was as long or longer.

Birmingham has recorded a case of absence of the ileo-colic valve, and Struthers has described several specimens in which the valve was imperfectly developed.

The ileo-colic valve begins to appear in the eighth to the tenth month of fetal life as an invagination of the ileum and of the adjacent walls of the cæcum and colon into the large intestine, and by the middle of fetal life it has developed into a blunt conical process, blocking up nearly

the whole of the adjacent cavity of the bowel. Towards the end of fetal life, and during early infancy, the large intestine grows more rapidly than the valve, so that the latter becomes relatively smaller in comparison with the diameter of the bowel. When the ileum is invaginated into the large intestine, a sharp bend is formed between the cæcum and colon, and the postero-median or mesenteric tænia of the longitudinal muscular coat bridges over the indentation and forms what has been described by Kraus [1] as the *habenula cœci.*

The wall of the anal canal differs in its structure from that of the intestine in being lined partly by skin and partly by mucous membrane, in the addition of striped to its non-striped muscle, and in the complete absence of a serous coat.

If the lower part of the rectum is empty, the longitudinal folds of its mucous membrane are prolonged down the upper part of the anal canal, and the radiating folds of skin below the canal extend a short distance up. An intermediate zone may be recognised, which in children is marked by a variable number of small recesses, called the anal sinuses, which open upwards and are bounded towards the lumen of the canal by semilunar folds—the anal valves. These structures usually disappear before adult life. This intermediate zone is covered by stratified squamous epithelium, and it probably corresponds to the union of the hind-gut with the proctodœum.

The circular muscular fibres of the rectum are continuous with a mass of non-striped fibres which surround the whole length of the anal canal and form the internal sphincter; while the longitudinal fibres of the rectum pass down the wall of the anal canal external to the internal sphincter and terminate in connective tissue which passes between some of the bundles of the external sphincter. These longitudinal fibres are joined by others, derived from the levator ani (see fig. 123), and probably assist in drawing up the skin which is protruded during defæcation.

The voluntary muscles round the anal canal are the external sphincter and the pubo-anal portions of the levatores ani (see fig. 123). With the internal sphincter, they form a mass of muscular tissue, the primary function of which is to close the anus. They may also assist in the expulsion of the fæces by contracting in a vermicular manner from above downwards.

Blood-vessels, lymphatics, and nerves of the large intestine.—The large intestine is supplied almost entirely by branches of the superior and inferior mesenteric **arteries,** but the lower end of the rectum and anal canal also get blood from the middle and inferior hæmorrhoidals. The superior mesenteric supplies the portion of the large intestine developed from the caudal limb of the intestinal loop, which projects through the umbilical opening in early fetal life: namely, the cæcum with its appendix, the ascending colon, and the right two-thirds of the transverse colon, while the inferior mesenteric gives branches to the portions of intestine formed from the hind-gut: namely, the left third of the transverse colon, the descending iliac and pelvic colon, and the greater part of the rectum. The branches of the superior mesenteric to the large intestine are the ileo-colic, the right colic (not constant), and the middle colic. The ileo-colic passes downwards and to the right in the root of the mesentery and gives branches to the end of the ileum, the vermiform appendix, the cæcum, and the lower part of the ascending colon. The appendicular branch descends behind the ileum, and runs in the meso-appendix—usually, close to its free border. This artery can be traced along the whole length of the appendix, and it usually gives off about five branches to it. The anterior cæcal branch passes into the ileo-colic fold and ramifies over the anterior surface of the cæcum, while a posterior cæcal goes to the back of the cæcum. The right colic passes outwards, behind the peritoneum, to reach the ascending colon, and divides into branches, which anastomose with the ileo-colic and middle colic. The middle

1 'Zur Anatomie der Ileo-cæcalklappe,' *Arch. f. klin. Chirurgie*, Bd. xliv., 1892.

colic arises just below the head of the pancreas, and enters the transverse meso-colon. It divides into two branches, which, generally, again subdivide, and they anastomose, forming a series of arcades lying near the colon. The left branch forms a long arcade with a branch of the left colic, and below this arcade there is a considerable area of the meso-colon almost destitute of blood-vessels. The inferior mesenteric artery arises from the aorta—usually under cover of the third part of the duodenum. It inclines downwards and outwards, passes over the left common iliac artery, and descends into the pelvis behind the root of the pelvic meso-colon to terminate as the superior hæmorrhoidal. The left colic is a large branch, which comes off near the origin of the inferior mesenteric, and courses upwards and outwards to supply the descending colon, and anastomose with the middle colic. The sigmoid branches come off from the inferior mesenteric—with the exception of the upper one, which often arises from the left colic—and supply the iliac and pelvic colon. The colic and sigmoid arteries form a continuous series of anastomosing arcades along the course of the colon, but the anastomosis is not so free between the two lowest sigmoid branches and between the lowest sigmoid and the superior hæmorrhoidal arteries.[1]

The most important artery for the supply of the rectum is the superior hæmorrhoidal. It is a single vessel which descends behind the rectum and then divides into two branches, which pass downwards, one on each side of the rectum. Their lower branches pierce the muscular coat, and run in a longitudinal direction under the mucous membrane, and anastomose freely with one another. In the anal canal, they lie in the longitudinal folds of the mucous membrane, and reach nearly as far as the verge of the anus.

The **veins** of the large intestine correspond generally with the arteries. The superior hæmorrhoidal vein commences in little dilatations in the folds of mucous membrane found in the upper part of the anal canal. These veins anastomose with the inferior hæmorrhoidal veins, and there is thus established an important communication between the portal and the inferior vena caval system of pelvic veins. The tributaries of the superior hæmorrhoidal vein ascend in the submucous coat of the rectum for about 6 cm., and, communicating with one another, form the hæmorrhoidal plexus. They pierce the muscular coat by five or six openings, and ultimately unite to form the trunk of the superior hæmorrhoidal, which is continued into the abdomen as the inferior mesenteric. This leaves the inferior mesenteric artery on the left side of the aorta, and, continuing to ascend, terminates in the splenic vein (see Quénu, 'Étude sur les veines du rectum et de l'anus,' *Bull. Soc. Anat.*, Paris, 1892).

The **lymphatic** vessels in the coats of the large intestine have the same general arrangement as in the small intestine, except in so far as they are modified by the absence of intestinal villi. They are stated to be more numerous in the cæcum and vermiform appendix than in the other parts of the large intestine. Kelly and Hurden[2] describe the lymphatic vessels in the appendix as arranged in three plexuses, lying respectively under the serous tunic, the circular muscular fibres, and the muscularis mucosæ, and only communicating slightly with one another; but Jamieson and Dobson[3] doubt this lack of communication, as they found all the lymphatics of the appendix could readily be injected from the submucous coat. The afferent vessels of the large intestine end in groups of lymphatic glands, which follow very closely the course of the blood-vessels, and the glands above the rectum are divided by Jamieson and Dobson[4] into the following chains: ileo-colic, meso-

[1] H. Drummond, 'The Arterial Supply of the Rectum and Pelvic Colon,' *Brit. Jour. of Surgery*, vol. i., No. 4, April 1914.

[2] *The Vermiform Appendix and its Diseases*, 1905.

[3] 'The Lymphatic System of the Cæcum and Appendix,' *Lancet*, April 27, 1907.

[4] 'The Lymphatics of the Colon,' *Proc. Royal Soc. of Medicine*, vol. xi., part iii., 1909.

colic, left colic, and inferior mesenteric, and each chain is said to consist of epicolic, paracolic, intermediate, and main groups. The afferent lymphatics ending in the ileo-colic glands, drain the portions of the intestine supplied by the ileo-colic artery. The glands on or near the intestine are the ileo-colic, lying in the ileo-colic fold of peritoneum; posterior ileo-colic, at the back of the junction of the ileum and ascending colon; a small gland in the meso-appendix, and glands along the mesenteric border of the terminal portion of the ileum and the median border of the ascending colon. The main group consists of ten to twenty glands, extending upwards along the course of the ileo-colic artery, and more or less distinctly continuous above with the main group of mesenteric glands. Jamieson and Dobson emphasise the fact that vessels from the cæcum or appendix may pass the glands in their immediate neighbourhood, and ascend to end directly in any of the glands of the main ileo-colic group. The epicolic glands, situated under the serous coat or in the appendices epiploicæ, are very small—most numerous in young subjects and on the pelvic colon. The lymphatic vessels of the rectum and anal canal are well developed, and form plexuses in the submucous and muscular coats. Those around the anal orifice terminate in the superficial inguinal glands, the others ascend in the wall of the rectum, pierce the muscular coat, and terminate mainly in glands in front of the sacrum, but a few pass outwards to the glands on the lateral wall of the pelvis.

The **nerves of the colon** resemble those of the small intestine in arising from the lower thoracic nerves and passing through the great splanchnics to the ganglia of the cœliac plexus. The non-medullated fibres issuing from this plexus accompany the branches of the superior and inferior mesenteric arteries going to the colon. The **nerves of the rectum** are very numerous and are derived from both the cerebro-spinal and the sympathetic systems. The former consist of branches derived from the sacral nerves, and the latter of offsets from the inferior mesenteric and hypogastric plexuses. Experiments upon animals have shown that the longitudinal muscular fibres of the rectum are supplied with motor fibres from the anterior roots of certain of the sacral nerves (second and third, and also the first in the dog), which nerves also supply inhibitory fibres to the circular coat, whereas the fibres of the hypogastric plexus, supplying the circular muscular tissue with motor fibres, are derived from white rami communicantes of the anterior roots of certain of the lumbar nerves, which join the sympathetic chain and lose their medullary sheath before passing to their distribution in the muscular coat. Pilliet has noted the presence of Pacinian corpuscles upon some of the nerves distributed to the anal mucous membrane. The normal mucous membrane of the intestine is not sensitive to tactile or painful stimuli, but the peritoneal covering is sensitive. The mucous membrane, for about an inch above the muco-cutaneous junction in the anal canal, is an exception to the above rule, as it is markedly sensitive. The skin at the verge of the anus is supplied by the fourth sacral nerve.

Variations in the large intestine.—The principal variations are due to irregular or defective development. In cases of complete transposition of the viscera, the cæcum lies in the left iliac fossa, and the iliac colon in the right. The proximal portion of the large intestine, as far as the left part of the transverse colon, may remain attached, along with the jejuno-ileum, to the posterior abdominal wall by a common mesentery, and the rotation of the intestinal loop, associated with the descent of the cæcum and the formation of a descending colon, may be permanently arrested in any part of its course. The descending colon may remain near the median plane and be connected with the front of the vertebral column by a mesentery. Occasionally, the rectum opens into the bladder or urethra, or it may terminate blindly, giving rise to the condition known as imperforate anus.

HEPAR.

The **liver** (hepar) is an external and internal secreting gland which is distinguished by its large size, the peculiar relation of its secreting cells to their ducts, and the fact that it receives a large amount of venous blood, which, in its passage through the organ, is brought, by a sinusoid arrangement of its capillaries, into direct contact with the liver-cells. It secretes the bile, and is also the seat of what is known as the glycogenic function. It is a solid mass of a yellowish brown colour; but when its vessels are filled with blood, it presents a dark red and somewhat mottled appearance. It is easily cut or lacerated, and is not infrequently ruptured during life from accidents, in which other parts of the body have escaped injury. When the substance of the liver is torn, the broken surface is not smooth, but coarsely granular—the liver being composed of a multitude of small lobules (*lobuli hepatis*) about 1 mm. in diameter, and consisting of liver-cells, blood-vessels, and ducts.

The liver is covered externally by a **serous coat** derived from the peritoneum. Connecting the serous coat to the glandular substance, and also present where the serous coat is absent, is a layer of areolar tissue, which is described as the **areolar** or **fibrous coat** of the organ. Its inner surface is connected with the delicate areolar tissue, which lies between the hepatic lobules. On the under surface of the liver is an opening into the organ called the porta hepatis, through which pass the portal vein, hepatic artery, hepatic duct, nerves, and lymphatic vessels. Opposite the porta, the fibrous tissue is greatly increased in amount and invests the entering and issuing vessels and duct, forming for them a loose but strong sheath of areolar tissue, which surrounds all their branches as they ramify through the organ, becoming more and more delicate, until it becomes continuous with the areolar tissue between the lobules. To this investment of areolar tissue, which encloses the three vessels above mentioned and their branches, the name **capsule of Glisson** has been applied, and the canals through the liver-substance which are occupied by those vessels and their 'capsule,' have been termed **portal canals.** At the back of the liver, where there is no serous coat, the areolar coat is also considerably thickened, and it here invests the hepatic veins as they issue from the organ to open into the vena cava inferior. These veins and their tributaries are also invested, in their course through the liver, by areolar tissue continuous with that of the areolar coat; but it is very small in amount, and binds the hepatic veins closely to the glandular substance, so that in section of these **hepatic canals** in the dead liver, the vein always remains patent, whereas in section of the portal canals, the looseness of the areolar tissue investing them and the large relative amount of this tissue, allow the branches of the portal vein to collapse, and this is their usual condition, if empty of blood. Both the portal and the hepatic canals conduct lymphatic vessels from the liver.

Form.—Its shape is liable to considerable variations, but is essentially that of a right-angled triangular prism, with the right angles rounded off.[1] If the upper part of the abdomen be supposed to be occupied by a cuboidal mass, divided into two by a cut passing from its upper left edge to its lower right one, the position and shape of the liver will be represented by the upper and right half of this mass, so that this organ presents five surfaces: namely—anterior, posterior, superior, inferior, and right; and its outline is triangular when viewed either from the front or the back. While the anterior surface is nearly flat and lies approximately in a coronal plane, the posterior surface is uneven, and towards the right presents a marked convexity, which projects backwards into the hollow on that side of the vertebral column.

[1] J. Symington, 'On Certain Physiological Variations in the Shape and Position of the Liver,' *Edinburgh Medical Journal*, February 1888.

Fissures or fossæ, and lobes.—A deep fissure (*fossa sagittalis sinistra*), situated near the median plane, extends backwards on the under-surface (*fossa venæ umbilicalis*), and then upwards on the posterior surface (*fossa ductus venosi*), partly dividing the liver into right and left lobes (*lobus hepatis dexter* and *lobus hepatis sinister*). The anterior part of the umbilical fissure extends on to the anterior surface of the liver, and forms a more or less distinct *incisura umbilicalis*. Above this notch, the line of demarcation between the right and left lobes is indicated on the anterior and upper surfaces of the liver merely by the attachment of a fold of peritoneum, termed the falciform ligament. Parallel to and on the right side of the left sagittal fossa are two depressions (*fossæ sagittales dextræ*). The anterior,

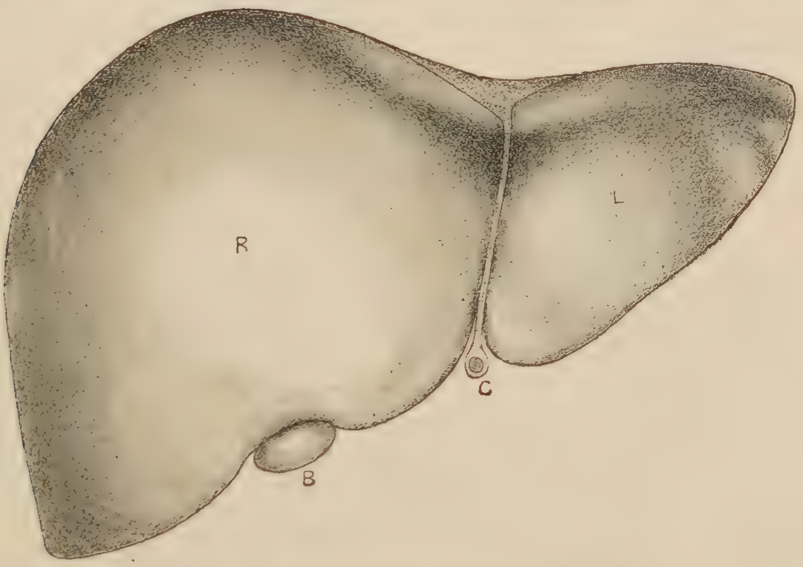


FIG. 128.—VIEW OF THE LIVER FROM THE FRONT. (J. Symington.)

R, right lobe; L, left lobe; B, fundus of gall-bladder; C, round ligament of liver.

placed on the under-surface, is a shallow impression for the lodgment of the gall-bladder (*fossa vesicæ felleæ*); the posterior forms a deep groove on the posterior surface of the liver, containing the inferior vena cava (*fossa venæ cavæ*). At the upper end of this fossa, several large hepatic veins emerge from the liver to join the inferior vena cava just below the diaphragm.

A deep fissure (*porta hepatis*) extends transversely between the posterior ends of the umbilical fissure and the fossa for the gall-bladder. It is through this opening that the hepatic artery and portal vein enter the liver, and the hepatic duct leaves this organ. On the under-surface of the right lobe of the liver, in front of the portal fissure, is a secondary lobe, named *lobus quadratus*; and on the posterior aspect, behind this fissure, another lobe, termed *lobus caudatus*. They will be described in connexion with the surfaces of the liver.

Surfaces and borders.—Of the five surfaces of the liver, three—the anterior, superior, and right—are parietal, being in close contact with the abdominal wall; one, the inferior, is visceral, while the posterior, although mainly parietal, is partly in close relation with abdominal organs. Some of the borders bounding these surfaces are thin and sharp, others thick and rounded.

The **anterior surface** (fig. 128) is frequently the largest of all the surfaces. It is smooth and triangular, and united with the upper and right surfaces by rounded

borders, but separated from the under-surface by a sharp border (*margo anterior*), which can often be felt in the living body. This surface is formed by both the right and left lobes, the separation between which is indicated by the umbilical notch and the attachment of the falciform ligament. To the right of the umbilical notch, the lower margin of this surface presents an excavation situated over the fundus of the gall-bladder. The peritoneum covers the whole of the anterior surface, except along a narrow line between the two layers of the above-named ligament.

The **posterior surface** (fig. 129) is triangular, very uneven, only partially covered by peritoneum, and not so distinctly marked off from the under-surface as is the anterior. It includes : (1) A portion of the left lobe, which is hollowed out for the lodgment of the abdominal portion of the œsophagus (*impressio œsophagea*),

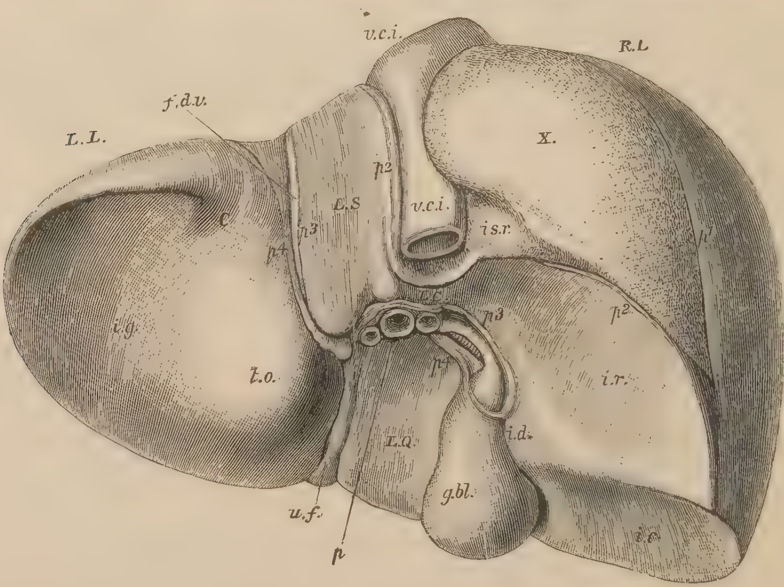


FIG. 129.—THE LIVER OF A YOUNG SUBJECT, SKETCHED FROM BELOW AND BEHIND. One-half natural size. (The drawing has been made by Mr. Wesley from a cast prepared under the direction of Prof. His of Leipzig.)

R.L., right lobe; *L.L.*, left lobe; *L.S.*, lobus caudatus; *L.C.*, processus caudatus; *L.Q.*, lobus quadratus; *p*, porta hepatis; *u.f.*, umbilical fossa; *f.d.v.*, fossa of the ductus venosus; *g.bl.*, gall-bladder; *v.c.i.*, vena cava inferior; *i.g.*, impression on the under-surface of the left lobe corresponding to the stomach; *C*, position of the cardia; *t.o.*, projection of the posterior surface of the left lobe against the lesser omentum (tuber omentale, His); *i.c.*, impressio colica; *i.r.*, impressio renalis; *i.sr.*, impressio supra-renalis; *i.d.*, impressio duodenalis; p^1, p^2, p^3, p^4, lines of reflection of the peritoneum; *X.*, surface of the liver uncovered by peritoneum.

and the right margin of the œsophageal opening in the diaphragm. This hollow gradually extends outwards, to end in the sharp posterior border of the left lobe of the liver, and is continuous below with the under-surface of the left lobe. (2) The *lobus caudatus* [Spigelii], often termed the Spigelian lobe, presents a quadrilateral surface looking backwards and inwards towards the diaphragm, and bounded by the fossa for the inferior vena cava on the right side and the fossa of the ductus venosus on the left. This lobe possesses another surface of about the same size, looking forwards and to the left, which is concealed in the fossa of the ductus venosus, and lies against the right or posterior layer of the lesser omentum, where this fold lies in the fossa of the ductus venosus (see fig. 130). The upper border of the caudate lobe corresponds to the top of the superior recess of the omental bursa; the lower is divided

by a shallow notch into two parts: a left, termed the *processus papillaris*, on account of its shape; and a right, the *processus caudatus*, which forms a ridge passing to the right between the portal fissure and the inferior vena cava, and becoming lost on the under-surface of the right lobe. The caudate lobe is opposite the tenth, eleventh, and twelfth thoracic vertebræ, and rests against the diaphragm, the two opposing surfaces being covered by peritoneum belonging to the omental sac. (3) To the right of the fossa for the inferior vena cava, is a large area, convex, except for a small depression at its lower and median corner, which receives the right suprarenal gland (*impressio suprarenalis, i.sr.*). In consequence of the separation of the layers of the coronary ligament, this surface of the right lobe (fig. 129, *X*) is not covered by peritoneum, except at its right extremity. It rests against the ascending part of the diaphragm, and superiorly passes gradually into the upper surface. Inferiorly, it is separated by a sharp margin from the renal impression on the under-

FIG. 130.—HORIZONTAL SECTION OF THE ABDOMEN OF A MAN, AGED FIFTY YEARS, AT THE LEVEL OF THE TWELFTH THORACIC VERTEBRA. One-third natural size. (P. T. Crymble.)

The distended stomach has pushed the left lobe of the liver over towards the right side. Lob. Spigelius = *lobus caudatus* [Spigelii].

surface. This margin is sloped obliquely downwards and outwards, following the line of the eleventh and twelfth ribs. The median border often projects over the inferior vena cava.

The **upper-surface** of the organ is smooth, covered by peritoneum, and exactly moulded to the under-surface of the diaphragm. Near the median plane, it gives attachment to the falciform ligament. It has two rounded convex portions, separated by a shallow concavity (*impressio cardiaca*), corresponding to the situation of the heart. The right convexity is much larger and more prominent than the left one.

The **under-surface** is concave, uneven, and looks downwards, backwards, and to the left. It is invested with peritoneum everywhere, except where the gall-bladder (fig. 129, *g.bl.*) is adherent to it, and at the *porta* (*p*), where the fold of peritoneum, termed the lesser omentum, which encloses the blood-vessels and ducts of the viscus, comes off, and passes to the smaller curvature of the stomach. The under-surface of the left lobe (*l.g.*) is moulded over the subjacent cardiac part of the stomach, and over that part of the anterior surface of the stomach which is next to the lesser curvature, and it has a rounded prominence termed the tuber omentale,

which rests against the lesser omentum. Occasionally—especially when the stomach is empty—the left part of this surface lies against the spleen.

The under-surface of the right lobe may be regarded as divided by the fossa which lodges the gall-bladder (*fossa vesicæ felleæ*), into two unequal portions. Of these, the lateral is by far the larger, and is mainly occupied by two large shallow concave impressions: one, situated anteriorly, being produced by the hepatic flexure of the colon (*impressio colica, i.c.*); the other, and posterior one, being caused by the right kidney (*impressio renalis, i.r.*). These two impressions are separated from one another by a low ridge. At the median border of the renal impression, is a third narrow and but slightly marked impression, corresponding to the descending part of the duodenum (*impressio duodenalis, i.d.*).

The median of the two parts, into which the fossa of the gall-bladder subdivides the under-surface of the right lobe, is somewhat rectangular and oblong, having the

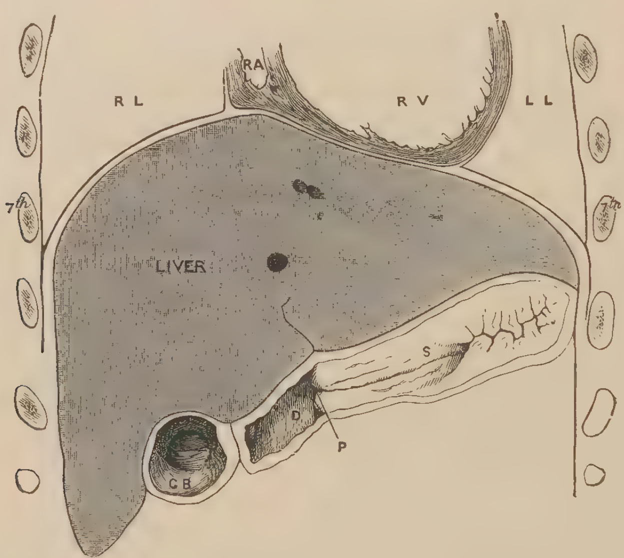


FIG. 131.—CORONAL SECTION OF PART OF THORAX AND ABDOMEN OF FEMALE CHILD, AGED ONE YEAR AND TEN MONTHS, VIEWED FROM THE FRONT. (J. Symington.)

The liver in the infant is relatively larger than in the adult and extends farther to the left.

R.L., right lung; L.L., left lung; R.A., right auricle of heart; R.V., right ventricle, distended with injection; S, stomach, empty and contracted; P, pylorus, situated in the median plane just beneath the fossa venæ umbilicalis of liver; D, first part of duodenum in contact with quadrate lobe of liver; G.B., gall-bladder, which was full of bile.

antero-posterior diameter greater than the transverse; it is known as the *quadrate lobe* (*L.Q.*). It is immediately over the pyloric end of the stomach and the commencement of the duodenum, and, when these are distended, they impress upon the surface of the quadrate lobe a slight concavity. It is bounded on the left by the umbilical fissure, and behind by the porta hepatis.

The **right surface** is convex from before backwards, and often slightly convex from above downwards. It unites with the upper, anterior, and posterior surfaces by rounded borders, but is separated below from the inferior surface by a sharp edge.

Position.—By far the greater part of the liver is situated to the right of the median plane. According to Cunningham's divisions (see p. 75) of the abdomen, it occupies the right hypochondrium and the epigastric regions, extending also

frequently into the left hypochondriac and right lumbar; but under Addison's scheme (see p. 80) of delimitation of the abdomen, it also lies in the right umbilical region. The anterior and right surfaces, in almost the whole of their extent, are

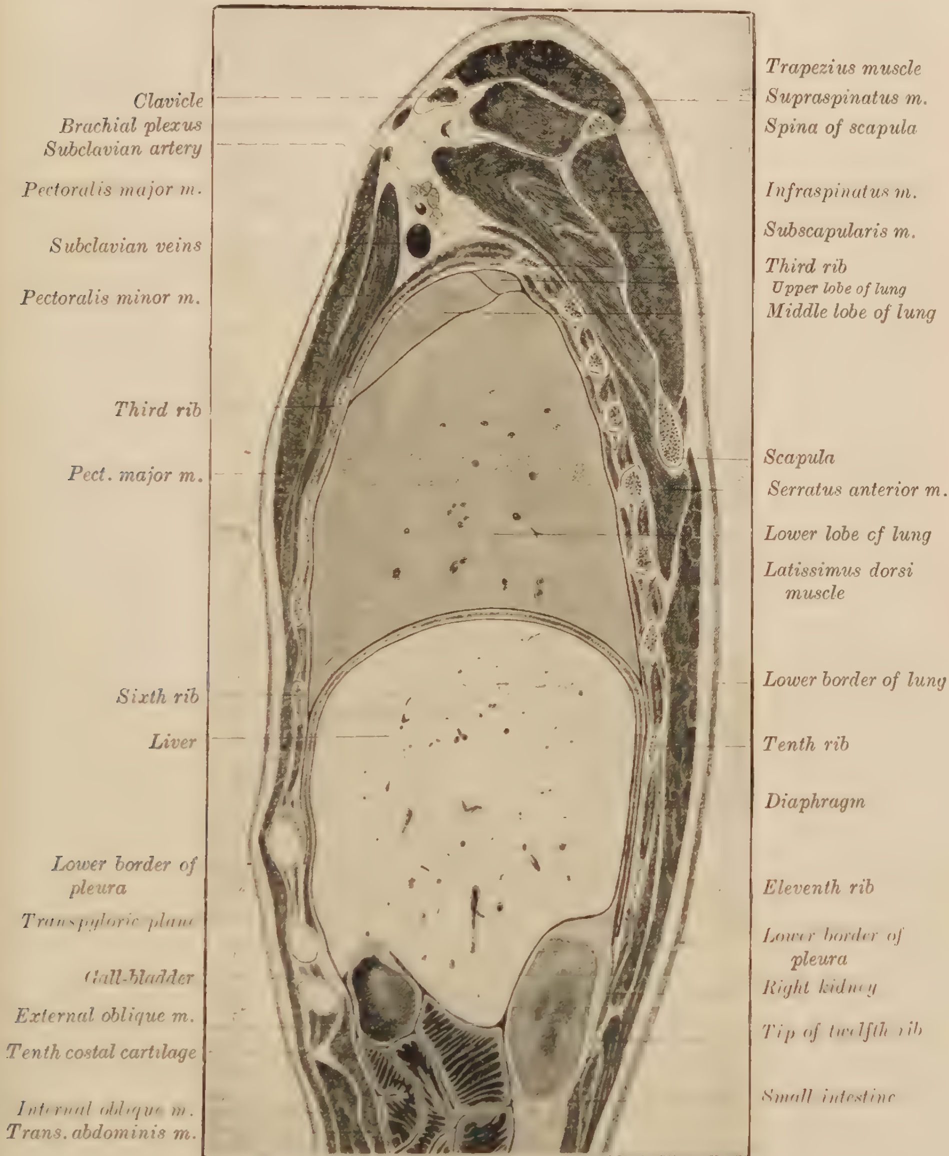


FIG. 132.—SAGITTAL SECTION OF THE TRUNK OF A MAN, AGED FORTY YEARS, MADE IN THE LINE OF THE RIGHT NIPPLE, VIEWED FROM THE MEDIAN ASPECT. One-third natural size. (J. S. Dickey.)

The section passed about 10 cm. to the right of the median plane and divided the liver 2·5 cm. median to the most prominent part of its right surface.

separated from the surface of the body by the lower ribs and costal cartilages, but in the subcostal angle, a small part of the anterior surface lies directly behind the abdominal wall. The right surface is protected by the seventh to the eleventh ribs,

and the anterior surface by the fifth, sixth, seventh, eighth, and ninth costal cartilages, with the anterior parts of the corresponding ribs, and by the ensiform cartilage—the diaphragm, of course, being interposed. Above, the liver is accurately adapted to the vault of the diaphragm, and the right lobe reaches higher beneath the ribs than the left, corresponding thus with the more elevated position of the diaphragm on the right side.

The upper limit of the liver may be indicated on the anterior wall of the chest by a line which crosses the median plane at the lower end of the body of the sternum. On the right side, this line must be extended outwards and slightly upwards, so that in the mammary line it is near the upper edge of the fifth rib, from which point it descends to join the right lateral surface. On the left side, the line passes nearly horizontally outwards, being slightly overlapped by the heart. The lower limit of the anterior surface on the right side practically coincides with the lower edge of the thoracic wall, as far inwards as the tip of the ninth costal cartilage. About this point, the line representing its lower edge passes upwards and to the left, to near the tip of the left eighth costal cartilage. It is then continued in the same direction across the left costal cartilages, to meet the left end of the upper limit at an acute angle.

The posterior surface of the right lobe of the liver lies in front of the ninth to the twelfth ribs, but it is separated from the chest wall not only by the diaphragm, but also by the right lung above and the right kidney below. Where the liver crosses the median plane, it is usually at the level of the tenth, eleventh, and twelfth thoracic, and the first lumbar vertebræ.

The right surface of the liver extends in the mid-axillary line from the seventh rib to the lower edge of the thoracic wall.

The situation of the liver is modified by the position of the body, and also by the movements of respiration. Thus, in the upright or sitting position, it descends to just below the lateral margin of the thorax; but in the recumbent posture, ascends half an inch or an inch higher up, and is entirely covered by the ribs, except a small portion opposite the sub-costal angle. During a deep inspiration, the liver also descends below the ribs—even in the recumbent posture—and in expiration retires up behind them. In females, it is often permanently forced downwards below the costal cartilages, owing to the use of tight stays; sometimes it reaches nearly as low as the crest of the ilium, and in many such cases its convex surface is indented from the pressure of the ribs.

The position of the liver is also affected by the condition of its neighbouring organs. Thus, when the intestines are distended and the abdomen prominent, the liver is pushed upwards, and its vertical extent diminished, while when these are empty and the abdominal wall retracted, the liver is compressed from before backwards, and the inferior surface is nearly in the same plane as the posterior. Again, with the distension of the stomach, the left lobe of the liver is pushed over towards the right side.

Ligaments and omentum.—The ligaments of the liver are, with one exception, simply reflexions of the peritoneum from the liver to adjacent structures. The *falciform ligament* connects the liver with the ventral wall of the abdomen and with the diaphragm. It forms a thin but extensive membrane, composed of two adherent layers of peritoneum, and extends from the under-surface of the diaphragm, and from the anterior abdominal wall as far down as the umbilicus, to the upper and anterior surfaces of the liver, and to the fossa of the umbilical vein on the under-surface. In addition to these attached borders, it presents a free margin, in the fold of which is situated the round ligament of the liver or obliterated umbilical vein. The length of the falciform ligament is such that it permits of a considerable lateral movement

of the anterior surface of the liver. The *coronary ligament* consists of two reflexions or folds of peritoneum, passing directly from the liver to the diaphragm, and bounding a large area on the posterior surface uncovered by peritoneum. The upper fold is continuous with the right layer of the falciform ligament, and passes outwards in front of the inferior vena cava, as this vessel emerges from the liver to pierce the diaphragm. It then inclines outwards and downwards on the posterior surface, to end in the small *right triangular ligament* of the liver. The lower fold passes inwards from this ligament, crossing the liver near the upper end of the renal impression and the lower part of the supra-renal impression, then goes in front of the inferior vena cava near the point where the vein joins the liver. From this level, it ascends on the median side of the inferior vena cava, and turns to the left to form the upper boundary of the superior recess of the omental sac (fig. 129). The left hepatic vein pierces the surface uncovered by peritoneum between the top of this recess and the superior layer of the coronary ligament.

The area bounded by the layers of the coronary ligament is the most fixed part of the liver, as the space to the right of the inferior vena cava is united by connective tissue directly to the diaphragm, while at the fossa venæ cavæ, the hepatic veins join the inferior vena cava immediately on leaving the liver. The left layer of the falciform ligament passes towards the left side, where it becomes continuous with the *left triangular ligament*. This ligament is attached to the diaphragm in front of the œsophageal opening and to the posterior part of the superior surface of the left lobe of the liver. It is a long loose fold, and allows a considerable movement of this part of the liver.

In addition to the folds called ligaments, the liver gives attachment to two layers of peritoneum, which pass between the liver and stomach, and form the *lesser omentum*. This is attached to the liver at the porta and the fossa ductus venosi, and near its right free border encloses between its two layers the bile-duct, portal vein, hepatic artery, lymphatics, and nerves.

Although a number of the peritoneal folds of the liver are called ligaments, they are of little use in maintaining the liver in position ; indeed, the peritoneal relations are such as to facilitate rather than to obstruct its movements. The liver is kept in position mainly by atmospheric pressure and surface tension, its convex aspect being moulded to the diaphragm like the opposing surfaces of a ball-and-socket joint. The tonicity of the muscular wall of the abdomen supports it below, while its connexion with the inferior vena cava, posteriorly, is an important factor in preventing its displacement.

MORPHOLOGY OF THE LOBES, FISSURES, AND PERITONEAL FOLDS OF THE LIVER.

The plan generally adopted of dividing the liver into two principal lobes— right and left— is a convenient and practical one ; but the data derived from a study of its comparative anatomy and development indicate that these two lobes do not represent the right and left halves of this organ.

We have already seen that the falciform ligament and part of the lesser omentum are attached to the liver between the right and the left lobes. This ligament and omentum are derived from the ventral meso-gastrium which, in an early stage of development, connects the stomach with the ventral wall of the abdomen. As the liver-bud grows into the meso-gastrium, it gradually divides it into a ventral portion—the falciform ligament—connecting the liver with the abdominal wall, and a dorsal part—the lesser omentum—uniting the liver and the stomach. It might be supposed that the attachment of these two folds to the liver would indicate the line of union of the right and left halves of the liver ; but it must be remembered that in the embryo, the liver has a much more extensive attachment to the abdominal wall than in the later months of fetal development, and that the place where the connexion persists is largely determined by the umbilical veins. Of the two umbilical veins originally present, the right disappears at an early stage, so that it is the left vein that comes to lie in the falciform ligament, and the ductus venosus

is an offshoot from this vein. It is evident, therefore, that the dividing-line between the two halves of the liver should be looked for to the right of the umbilical fissure; so that Cantlie's contention [1] that this line passes from the fundus of the gall-bladder, backwards, to the entrance of the hepatic veins into the inferior vena cava, is reasonable.

Rolleston, Owen, Flower, and other comparative anatomists made more or less successful efforts, by an examination of the external form of the liver, to determine the typical number and position of the lobes of the liver and to ascertain the pecularities of the human liver as compared with the mammalian type. Rex [2] introduced a new and very valuable method of determining lobar homology when he investigated the mode of distribution of the branches of the portal vein within the liver, and much new light has been thrown upon the question by the embryological researches of Mall,[3] Charnock Bradley,[4] and many others. The typical mammalian liver consists of three lobes—a central, and a right and a left lateral. The central lobe may be divided into a right and a left, and each lateral lobe may have attached to it an additional lobe—omental or Spigelian on the left side, and caudate on the right. According to Rex, the two main divisions of the portal vein give off branches for the supply of these lobes, as is seen from the following table taken from Charnock Bradley's paper:—

Lobes.	Branches of Portal Vein.
Caudate	Ramus descendens.
Right lateral . . .	Ramus arcuatus.
Right central . . .	Ramus cysticus. Right arborisation from the recessus umbilicalis.
Left central	Left arborisation from the recessus umbilicalis.
Left lateral	Ramus angularis.
Omental lobe . . .	Ramus omentalis.

According to Brachet,[5] the liver of the rabbit embryo, twelve days old, consists of three lobes: a ventral, and right and left lateral. The former is developed in association with the umbilical veins, and the latter with the omphalo-mesenteric veins. Mall and Charnock Bradley have also shown the intimate relation which exists, in the developing human and pig's liver, between the number of lobes and the branches of the blood-vessels.

Great variation exists, even in mammals belonging to the same order, with regard to the extent to which the liver is subdivided by true lobar fissures, and no satisfactory explanation has yet been given of these facts.

The human liver belongs to the type in which the lobes are feebly marked; indeed, the only two that can definitely be recognised are the Spigelian and the caudate. The Spigelian (caudate of *B.N.A.*) is fairly distinct; but the caudate is so small that in the *B.N.A.* it is named the caudate process. These two lobes are better marked in the fetus than in the adult.[6] Fissures and processes are occasionally met with in the human liver, which may represent permanent markings in certain of the primates. Thus Ruge [7] has described a *processus pyramidalis* in various primates, which projects from the left lobe near the umbilical fissure, and Thompson and Taylor[8] found it occasionally present in man.

Blood-vessels, lymphatics, and nerves.—The two vessels by which the liver is supplied with blood are the *hepatic artery* and the *portal vein*. The **hepatic artery**—a branch of the cœliac artery—is small in comparison with the organ to which it is distributed. It enters the porta, and there divides into right and left branches, which divide and subdivide in the portal canals. It is distributed to the connective tissue of the liver, to the coats of the hepatic ducts, and portal veins; and some of its branches assist in the formation of the interlobular plexus, situated between the hepatic lobules.

[1] 'On a New Arrangement of the Right and Left Lobes of the Liver,' *Jour. Anat. and Phys.*, vol. xxxii., 1898.
[2] 'Beiträge zur Morphologie der Säugerleber,' *Morph. Jahrbuch*, Bd. xiv., 1888.
[3] 'A Study of the Structural Unit of the Liver,' *Amer. Jour. Anat.*, vol. v., 1906.
[4] 'A Contribution to the Morphology and Development of the Mammalian Liver,' *Jour. Anat. and Phys.*, vol. xviii. 1909.
[5] 'Recherches sur le développement du diaphragme et du foie chez le lapin,' *Jour. de l'Anat. et de la Phys.*, t. xxxi., 1895.
[6] A. Thomson, 'The Morphological Significance of Certain Fissures in the Human Liver,' *Jour. Anat. and Phys.*, vol. xxxiii., 1899.
[7] 'Die aüsseren Formerhältnisse der Leber bei der Primaten,' *Morph. Jahrbuch.*, Bd. xxix.
[8] *Jour. Anat. and Phys.*, vol. xxxix.; *Proc. Anat. Soc.*, May 1905.

By far the greater part of the blood which passes through the liver—and in this respect it differs from all other organs of the human body—is conveyed to it by a large vein, the **portal vein** or vena portæ (fig. 137). This vein is formed by the union of the veins of the stomach, intestines, pancreas, and spleen. It enters the porta, and, like the hepatic artery, there divides into two principal branches, which subdivide in the portal canals and end in the interlobular plexuses. As the branches ramify in the liver, they do not anastomose with one another and do not come to the surface of the organ (Mall). The vessels forming the interlobular plexuses pass into the lobules of the liver, and form between the rows of liver-cells intralobular plexuses (see figs. 137 and 138), which join intralobular veins in the centre of the lobules.

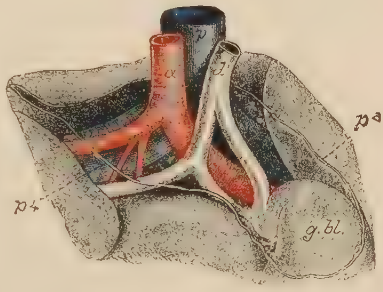


FIG. 133.—SKETCH OF A PORTION OF THE UNDER-SURFACE OF THE LIVER, SHOWING THE ARRANGEMENT OF THE VESSELS IN THE PORTAL FISSURE. (G. D. Thane.)

a, hepatic artery; *p*, portal vein; *d*, common bile-duct; *g. bl.*, gall-bladder; p^3, p^4, lines of reflection of the peritoneum.

Rex[1] showed that the left main branch of the portal vein is not distributed solely to the left lobe of the liver, but that it also supplies certain parts of the right lobe. He further demonstrated that the right and left main branches give off secondary ones, which supply areas corresponding to the typical lobes of the liver.

The **hepatic veins** (fig. 135), which convey the blood away from the liver, arise as the central veins of the lobules; these join sublobular veins, which unite to form the hepatic veins. The hepatic veins end by two or three principal trunks, besides a number of smaller ones, in the vena cava inferior. In the liver, these veins pursue an entirely different course from the other vessels. The hepatic veins sometimes anastomose with one another, and often come to the surface of the liver (Mall).

FIG. 134.—SECTION OF A PORTAL CANAL. Magnified. (E. A. Schaefer.)

a, branch of hepatic artery; *v*, branch of portal vein; *d*, hepatic duct; *l*, *l*, lymphatics in the areolar tissue of Glisson's capsule which encloses the vessels.

The **lymphatics** of the liver, large and numerous, form a superficial and a deep set.

The superficial set forms a rich subperitoneal plexus. Some of those on the upper surface join, through the suspensory ligament and diaphragm, the sternal glands, and others pass between the layers of the coronary ligament and through the inferior vena caval opening of the diaphragm to the anterior mediastinal glands. From the under-surface of the liver, vessels pass to various groups of glands associated with neighbouring viscera, such as the pancreas and stomach. The deep lymphatics run mainly in the portal canals and in the lesser omentum, with the portal vein and hepatic artery, and end in glands (hepatic) situated along the course of the hepatic, cystic, and gastro-duodenal arteries, and towards the left side in the cardiac and pancreatico-lienal groups of glands. Some deep lymphatic vessels arise around the sublobular veins and leave the liver with the hepatic veins.

1 'Beiträge zur Morphologie der Säugerleber,' *Morph. Jahrbuch.*, Bd. xiv., 1888.

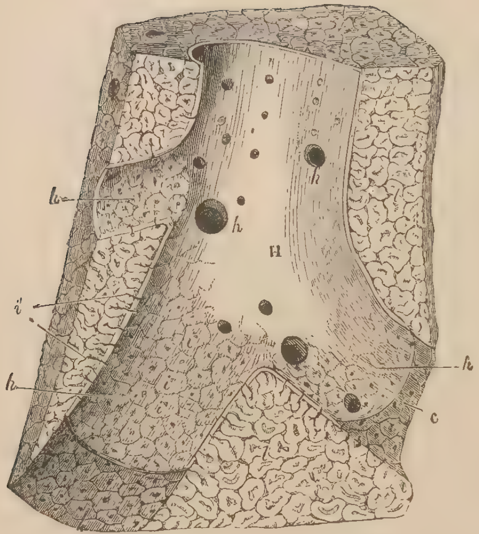


FIG. 135.—SECTION OF A PORTION OF LIVER PASSING LONGITUDINALLY THROUGH A CONSIDERABLE HEPATIC VEIN, FROM THE PIG. About five diameters. (Kiernan.)

H, hepatic venous trunk, against which the sides of the lobules are applied; *h*, *h*, *h*, three sublobular hepatic veins, on which the bases of the lobules rest, and through the coats of which they are seen as polygonal figures; *i*, mouth of the intralobular veins, opening into the sublobular veins; *i'*, intralobular veins shown passing up the centre of some divided lobules; *c*, *c*, walls of the hepatic venous canal, with the polygonal bases of the lobules.

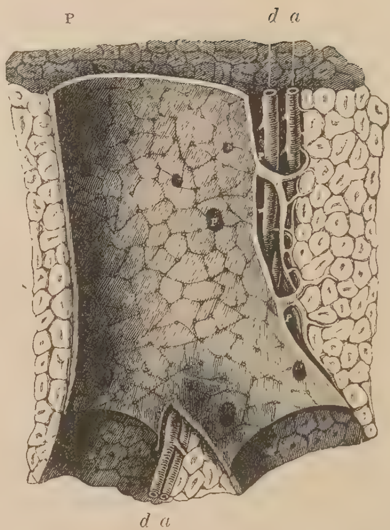


FIG. 136. — LONGITUDINAL SECTION OF A PORTAL CANAL; CONTAINING A PORTAL VEIN, HEPATIC ARTERY, AND HEPATIC DUCT, FROM THE PIG About five diameters. (Kiernan.)

P, branch of vena portæ, situated in a portal canal, formed amongst the lobules of the liver; *p*, *p*, larger branches of portal vein, giving off smaller ones named interlobular veins; there are also seen within the large portal vein numerous orifices of interlobular veins arising directly from it; *a*, hepatic artery; *d*, biliary duct; at *c*, *c*, the venous wall has been partially removed.

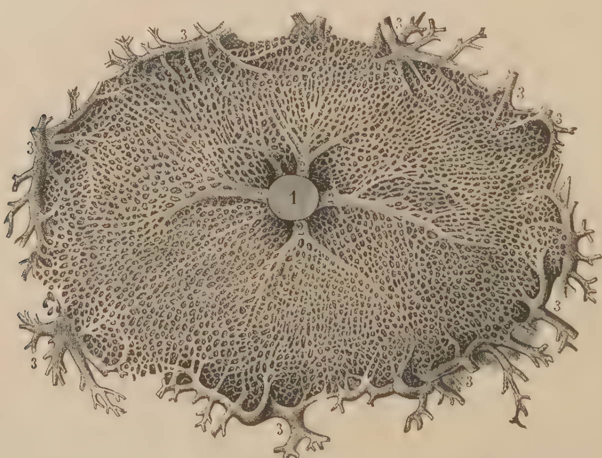


FIG. 137.—CROSS SECTION OF A LOBULE OF THE HUMAN LIVER, IN WHICH THE CAPILLARY NETWORK BETWEEN THE PORTAL AND HEPATIC VEINS HAS BEEN FULLY INJECTED. Sixty diameters. (Sappey.)

1, section of the intralobular or central vein; 2, its smaller branches collecting blood from the capillary network; 3, interlobular or peripheric branches of the vena portæ with their smaller ramifications passing inwards towards the capillary network in the substance of the lobule.

The **nerves** are derived partly from the cœliac plexus, and partly from the vagi nerves—especially from the left vagus. They enter the liver, supported by the hepatic artery and its branches, along with which they may be traced in the portal canals. The sensory nerves of the liver are probably derived from the seventh, eighth, ninth, and tenth thoracic spinal nerves.

Dimensions and weight.—The greatest vertical extent of the liver is near its right surface, where it measures, on an average, from 14 cm. to 17 cm. This diameter gradually diminishes from right to left, the organ ending on the left side in a thin

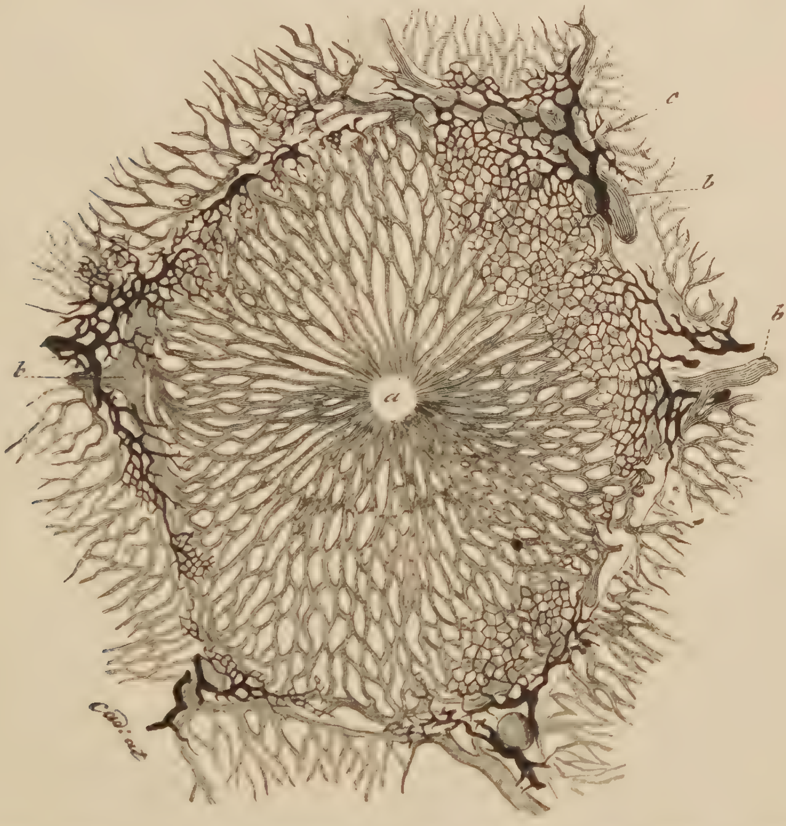


FIG. 138.—SECTION OF A LIVER-LOBULE WITH THE BLOOD-VESSELS AND DUCTS INJECTED. (Cadiat.)

b, *b*, interlobular veins; *a*, intralobular vein; *c*, interlobular bile-ducts, with which the bile analiculi, or ductus biliferi, from the lobule are connected. The biliferous ducts have only become injected in the peripheral parts of the lobule.

sharp border. Its greatest transverse diameter is usually several centimetres more than the corresponding vertical one, but is sometimes less. The antero-posterior diameter is greatest on the right side of the vertebral column, and just above the right kidney; here it measures from 12 cm. to 15 cm. In front of the vertebral column its antero-posterior extent is considerably reduced, being in the median plane only about 8 cm. to 10 cm. The ordinary volume of the liver is about 1500 c.c., and its average weight 1550 grms. According to the facts recorded by Reid, the liver weighed, in forty-three cases out of eighty-two, between 48 and 58 ounces, in the adult male; and, in seventeen cases out of thirty-six, between 40 and 50 ounces, in the adult female. It is generally estimated to be equal

to about one thirty-sixth of the weight of the whole body; but in the fetus, and in early life, its proportionate weight is greater. Thus at birth it is about one-eighteenth of the body-weight.

Vierordt (*Anatom. Daten u. Tabellen*) gives the following approximate numbers for the adult: Weight, male 1579 grms., female 1526 grms.; volume, 1720 c.c.; length, 320 mm.; sagittal diameter, 200 mm.

The specific gravity of the liver is between 1·05 and 1·06; in fatty degeneration this is reduced to 1·03, or even less.

Liver in the infant.—The liver is relatively much larger in the new-born child than in the adult. Indeed, at birth, it occupies nearly one-half of the abdominal cavity. The left lobe, as compared with the right, is distinctly larger than in the adult, and often reaches to the left, so as to come in contact with the lateral wall of the abdomen on that side, presenting in this position a distinct left surface. In such cases, Ballantyne[1] describes the anterior surface as being more nearly quadrilateral than triangular. According to this authority, the anterior surface of the liver in the new-born infant corresponds in its vertical extent in the median plane with the last four thoracic and upper two lumbar vertebræ, and its lower border is within 2 cm. of the umbilicus. Its vertical extent increases from left to right, the lower edge of the right surface coming within 1 cm. or 1·5 cm. of the right iliac crest.

Varieties.—The liver is not subject to great or frequent deviation from its ordinary form and relations. It has been found without any division into lobes. On the other hand, Sœmmerring has recorded a case in which the adult liver was divided into twelve lobes, and similar cases of subdivided liver (resembling that of some animals) have been now and then observed by others. A detached portion, forming a sort of *accessory* liver, is occasionally found appended to the left extremity of the gland by a fold of peritoneum containing blood-vessels. I. Broman (*Normale und abnormale Entwickelung des Menschen*, 1911) mentions two additional lobes which may occur, and which he regards as atavistic—namely: the *lobus posterior*, projecting through the hiatus bursæ omenti majoris, so as to lie behind the stomach; and the *lobus venæ cavæ*, projecting downwards along the course of the inferior vena cava.

The *fossa venæ umbilicalis* is often bridged over by a piece of liver substance, called the pons hepatis. It unites the quadrate and left lobes, and varies considerably in size. The upper surface sometimes shows longitudinal furrows, which are occupied, when the organ is *in situ*, by folds of the diaphragm. J. Buy ('Les sillons diaphragmatique du foie,' *Bibliog. Anat.*, t. xiii., 1904) discusses fully the position, number, relation to diaphragm, &c., of these furrows and the various theories that have been advanced to account for their presence. He supports the view that they are due to lateral compression of the thorax.

Various cases have been described of unusual mobility of the liver in women with flaccid and often pendulous abdominal walls (see Landau, *Die Wanderleber und der Hängebauch der Frauen*, 1888).

Bile-passages and gall-bladder.—The bile, secreted by the liver-cells, passes into minute channels between them, termed the ductus biliferi, and at the periphery of the hepatic lobules these ducts end in the interlobular hepatic ducts (fig. 138), and from these arise the hepatic ducts traversing the portal canals, along with the branches of the portal vein and hepatic artery, and, finally, uniting at the porta of the liver into a right and a left branch. Outside the liver, the bile-passages consist of the hepatic duct, the cystic duct, the gall-bladder, and the common bile-duct.

The **hepatic duct**, formed by the union of a right and a left branch, which issue from the bottom of the porta and unite at a very obtuse angle, descends to the right, within the lesser omentum, in front of the vena portæ, and with the hepatic artery to its left. Its diameter is about 4 mm. and its length nearly 5 cm. At its lower end, it meets with the cystic duct (descending from

[1] 'The Relations of the Abdominal Viscera in the Infant,' *Trans. Medico-Chir. Soc. of Edinburgh*, vol. x. (new series), 1890–91.

the gall-bladder), and the two ducts uniting together at an acute angle form the common bile-duct.

The **gall-bladder** (*vesica fellea*) (fig. 129, *g.bl.*), is a pear-shaped membranous sac, 7·5 cm. to 10 cm. long, about 35 mm. across its widest part, and capable of containing from 30 c.c. to 50 c.c. It is lodged obliquely in the fossa, before mentioned, on the under-surface of the right lobe, with its large end or *fundus*, which projects beyond the anterior border of the liver, directed forwards, downwards, and to the right, whilst its *neck* is inclined in the opposite direction. Its upper-surface is attached to the liver by areolar tissue. Its under-surface and fundus are covered by the peritoneum, which is reflected over them from the surface of the liver. In rare cases, the peritoneum completely surrounds the gall-bladder, which is then suspended by a sort of mesentery from the under-surface of the liver. The fundus generally touches the abdominal parietes immediately beneath the margin of the thorax, opposite the ninth costal cartilage. It is, however, subject to considerable variations. Thus, if the liver be small, or the gall-bladder empty, it often fails to reach the abdominal wall. In cases of distension of the stomach, it may be displaced to the right. The gall-bladder rests below on the commencement of the transverse colon; and, farther back, it is in contact with the duodenum, and sometimes with the pyloric extremity of the stomach. The neck, gradually narrowing, passes upwards and forwards, and then turns downwards to end in the cystic duct.

The gall-bladder is supplied with blood by the cystic artery, a branch of the right division of the hepatic artery, along which vessel it also receives nerves from the cœliac plexus. The cystic veins empty themselves into the vena portæ.

The **cystic duct** is about 15 mm. long, and only about 2·3 mm. wide. It runs downwards, backwards, and to the left, and unites with the hepatic duct to form the common bile-duct. The terminal portion of the cystic duct runs for a variable distance parallel with and adherent to the hepatic duct.

The **common bile-duct** (*ductus choledochus*), about 5·6 mm. to 7·5 mm. in width, and nearly 7 cm. in length, conveys the bile into the duodenum. It passes downwards, backwards, and to the left, continuing the course of the hepatic duct, between the layers of the lesser omentum, in front of the vena portæ, and to the right of the hepatic artery. Passing behind the first part of the duodenum, it bends to the right and somewhat backwards to gain the inner and posterior aspect of second part of the duodenum, covered by or included in the head of the pancreas, and for a short distance in contact with the right side of the pancreatic duct. Together with this duct, it then perforates the muscular wall of the duodenum, and, after running obliquely for about 15 mm. between its coats, and forming an elevation beneath the mucous membrane, it becomes somewhat constricted, and opens by a common orifice, with the pancreatic duct on the inner surface of the intestine, near the junction of the second and third portions of the duodenum, and 7 cm. to 10 cm. beyond the pylorus.

Varieties—The gall-bladder is occasionally wanting, in which case the hepatic duct is much dilated within the liver, or in some part of its course. Sometimes the gall-bladder is irregular in form, or is constricted across its middle, or—but much more rarely—it is partially divided in a longitudinal direction. Purser (*Trans. Acad. Med., Ireland*, vol. v.) has recorded a case in which there were two distinct gall-bladders, each having a cystic duct which joined the hepatic duct. The gall-bladder has been found on the left side (Hochstetter, *Arch. f. Anat.*, 1886) in subjects in which there was no general transposition of the thoracic and abdominal viscera. Direct communications, by means of small ducts (named hepato-cystic), passing from the liver to the gall-bladder, exist regularly in various animals.

The right and left divisions of the hepatic duct sometimes continue separate for some distance within the lesser omentum. Lastly, the common bile-duct not infrequently opens separately from the pancreatic duct into the duodenum.

THE PANCREAS.

The pancreas (figs. 139 to 143) is a long gland of a reddish cream colour, and irregularly prismatic shape, which lies across the posterior wall of the abdomen, behind the stomach, and opposite the first and second lumbar vertebræ. Its right end is the larger, and is termed the *head*; from this arises a short and slightly constricted *neck*, which connects the head with the *body*. The body

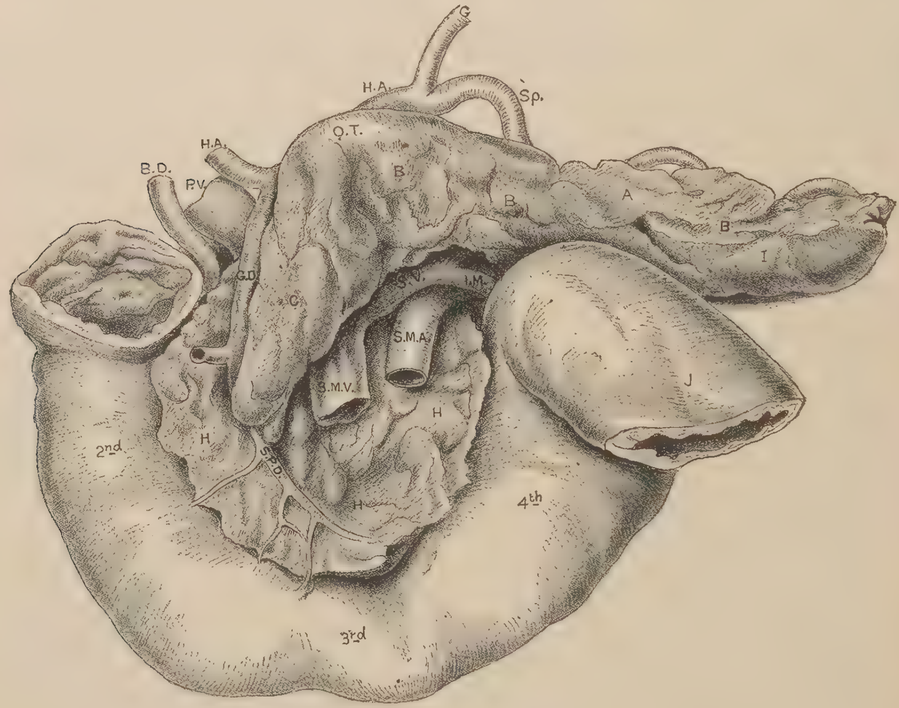


Fig. 139.—Anterior aspect of the pancreas, etc. (J. Symington.)

Drawn by G. C. R. Harbinson, from a specimen prepared by hardening the abdominal viscera *in situ* by the injection of a 1 per cent. solution of chromic acid.

H.H.H., head of pancreas; C., its neck; B.B., its body; A., anterior surface of the body; I., its inferior surface; O.T., omental tuberosity near right end of body; 2nd, 3rd, 4th, corresponding parts of the duodenum; J., jejunum; H.A., hepatic artery; G., gastric artery; S.P., splenic artery; G.D., gastro-duodenal artery; S.P.D., superior pancreatico-duodenal artery; S.V., splenic vein; I.M., inferior mesenteric vein; S.M.V., superior mesenteric vein; P.V., portal vein; B.D., common bile-duct.

passes to the left, its free extremity or *tail* touching the spleen. About one-third of the gland lies to the right of the median plane and two-thirds to the left.

The pancreas varies considerably, in different cases, in its size and weight. It is usually 12 cm. to 14 cm. long, and 10 mm. to 20 mm. in thickness. The weight of the gland, according to Krause and Clendenning, is usually from 66 grms. to 102 grms. Its specific gravity is 1·046.

The head (fig. 139, H) of the pancreas forms a disk-shaped mass, flattened from before backwards, and lying in the concavity formed by the second, third, and fourth parts of the duodenum, to which it is closely united. The superior mesenteric vessels are in contact with the anterior surface, near its left border; while near its lower end, it is crossed by the transverse colon and its meso-colon. The superior and inferior pancreatico-duodenal vessels pass down in front of the head a short distance from its right and left borders, respectively. Posteriorly, it lies upon the

inferior vena cava, the left renal vein, and the aorta. The common bile-duct passes down behind it, and is generally received into a groove or canal in its substance. The lower part of the head, which extends downwards to the third part of the duodenum, and turns to the left behind the mesenteric vessels, is known as the uncinate process.

The *neck*[1] of the pancreas (fig. 139, C) is about 2 cm. long. It springs from the upper part of the anterior surface of the head and turns upwards, forwards, and to the left to join the body. In its course, it passes in front of the termination of the superior mesenteric vein and the commencement of the vena portæ. At its attachment to the head, it is grooved on its right side by the gastro-duodenal and

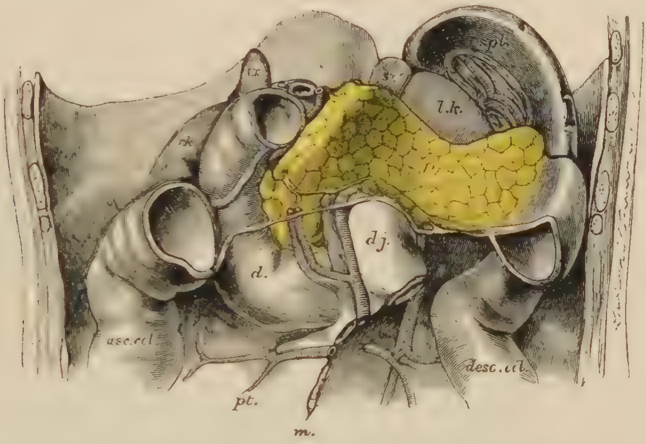


FIG. 140.—THE PANCREAS AND ADJOINING VISCERA FROM BEFORE.
This and the next figure are drawn from Prof. His's model. One-third natural size.

The liver, the stomach, the greater part of the small intestine, and the transverse colon have been removed. *P*, pancreas; *d*, duodenum; *d.j.*, duodeno-jejunal flexure; above the duodenum, and between it and the head of the pancreas, are seen the bile-duct, portal vein, and hepatic artery; *asc. col.*, *desc. col.*, ascending and descending colon; *spl.*, spleen; *r.k.*, *l.k.*, right and left kidneys; *s.r.*, *s.r′.*, right and left suprarenal glands; *pt.* peritoneum at the back of the abdominal cavity; *m*, line of reflection of the mesentery; the line of reflection of the transverse meso-colon is seen along the lower edge of the pancreas and crossing the duodenum.

superior pancreatico-duodenal arteries. The first part of the duodenum lies against its anterior and right aspect, and the pylorus often touches it when the stomach is distended.

The *body* and *tail* together (fig. 139, B) are 10 cm. to 12 cm. long. After crossing from the right side in front of the aorta, the body curves backwards in its course to the left, and ends in contact with the lower part of the anterior surface of the spleen. Towards its right end, where the body of the pancreas lies anterior to the vertebral column, it is flattened from before backwards so that it has only two distinct surfaces—anterior and posterior; but to the left of the vertebral column, it usually possesses also a fairly well-marked inferior surface (see fig. 174).

The anterior surface is concave, looks upwards as well as forwards, and is covered by the stomach—the lesser sac of the peritoneum intervening—except for an area, variable in size, where the stomach or first part of the duodenum may be in direct contact with it. Towards the upper part of its right end, it often presents a well-marked prominence (fig. 142), called the tuber omentale (His), which is separated from the liver by the lesser omentum.

The posterior surface lies in front of the aorta, the cœliac plexus of nerves, the

[1] Symington, 'On the Topographical Anatomy of the Pancreas, with Remarks on the Arrangement of its Ducts,' *Trans. Royal Acad. of Medicine of Ireland*, vol. xiii., 1895.

origin of the superior mesenteric artery, the pillars of the diaphragm, the splenic vein, the left kidney and its vessels, and the left supra-renal gland.

The inferior surface rests on the duodeno-jejunal flexure, some convolutions of the jejuno-ileum, and, near its left end, the transverse colon.

The superior border lies in relation with the cœliac artery, the hepatic branch of this trunk passing to the right just above it, while on the left side the splenic artery in its tortuous course to the spleen grooves it.

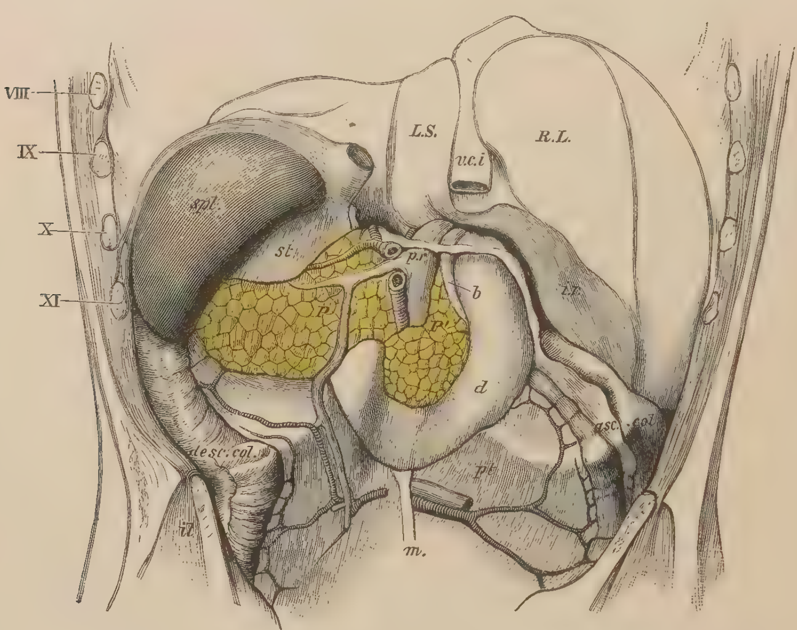


Fig. 141.—View of the pancreas and adjacent abdominal viscera from behind, after removal of the whole of the posterior wall of the abdomen, and the kidneys and suprarenal glands; the peritoneum being left. One-third natural size.

P, pancreas; *P'*, its head; *d*, duodenum; *st.*, stomach; *spl.*, spleen; *R.L.*, right lobe of the liver; *L.S.*, caudate lobe; *v.c.i.*, vena cava inferior; *p.r.*, portal vein; *b*, common bile-duct; *i.r.*, impression for the right kidney on the posterior surface of the liver; the situation of the two kidneys is well shown by the corresponding impressions in the cast; *asc. col.*, *desc. col.*, ascending and descending colon; *pt.*, back of the peritoneum; *m*, line of attachment of the mesentery; VIII, IX, X, XI, the corresponding ribs; *il.*, ileum.

At the anterior border, the two layers of the transverse meso-colon separate; the anterior layer ascending in relation with the anterior surface of the pancreas, while the posterior layer passes backwards in contact with the inferior surface. The posterior surface is thus devoid of peritoneum, while the anterior surface is related to the bursa omentalis, and the inferior surface to the great sac of the peritoneum.

The tail of the pancreas is in contact with the lower part of the inner surface of the spleen, and is bounded in front by the stomach and behind by the left kidney.

The transpyloric plane usually corresponds approximately to the lower border of the body and tail of the pancreas, while the head turns downwards to the right of the median plane, and is situated in great part below the transpyloric plane, so that the head of the pancreas lies in the right umbilical and right epigastric, and the body and tail in the left epigastric and left hypochondriac regions (fig. 78).

Ductus pancreaticus.—The principal excretory duct, called the *pancreatic duct* or *canal of Wirsung*, runs through the entire length of the gland from left to right, buried entirely in its substance. Commencing by the union of the small ducts, derived from the groups of lobules composing the tail of the pancreas, and receiving in succession at various angles and from all sides the ducts from the body of the gland, the canal of Wirsung pursues a nearly straight course in the axis of the gland until it reaches the neck. Here it turns obliquely downwards, backwards, and to the right through the neck and head, gradually approaching the posterior surface of the latter. Near its termination it comes in contact with the left side of the common bile-duct, which it accompanies to the second part of the duodenum. As the duct passes through the body of the pancreas, it lies rather nearer the upper

FIG. 142.—HORIZONTAL SECTION OF THE ABDOMEN OF A MAN, AGED FIFTY YEARS, AT THE LEVEL OF THE FIRST LUMBAR VERTEBRA. One-third natural size. (P. T. Crymble.)

The neck and part of the body of the pancreas are exposed lying behind the omental bursa, the stomach, the lesser omentum, and the liver.

than the lower border, and the dorsal than the ventral surface. As it traverses the head of the pancreas, it is joined by numerous branches, one of which, coming from the lower part of the head, is larger than the others. The bile and pancreatic ducts, placed side by side, pass very obliquely through the muscular and areolar coats of the intestine, and terminate, as already described, on its internal surface, by a common orifice, situated near the junction of the second and third portions of the duodenum, between 8 cm. and 10 cm. below the pylorus. The pancreatic duct, with its branches, is readily distinguished within the glandular substance, by the very white appearance of its thin fibrous walls. Its widest part, near the duodenum, is from 2 mm. to 3 mm. in diameter, or nearly the size of an ordinary quill. It is lined by a remarkably thin and smooth membrane, which, near the termination of the duct, may present a few scattered recesses.

Ductus accessorius, or duct of Santorini.—In addition to the main duct, there is almost invariably another, much smaller in size, which leaves the main duct a little to the right of the neck of the gland, and, passing outwards, opens into the duodenum on a small papilla about 2 cm. above the common orifice of the bile and pancreatic ducts. It drains the upper and anterior part of the head of the pancreas.

The accessory duct often narrows as it approaches the duodenum. On the other hand, it may be enlarged, and serve as the main channel for the discharge of the pancreatic juice into the duodenum.

The presence of two ducts is explained by a reference to the development of the pancreas. There are two outgrowths from the duodenum to form the pancreas: one dorsal and the other ventral—the latter being closely associated with the biliary diverticulum. The dorsal outgrowth is the more active, forming the whole of the gland except the lower part of the head. The two glandular masses and their ducts join, and the portion of the dorsal duct on the duodenal side of the junction, growing less rapidly than the ventral duct, becomes the accessory duct; while the distal portion of the dorsal duct and the ventral duct form the main pancreatic duct. For accounts of special observations on the arrangement of the pancreatic ducts, consult Schirmer (*Beiträge zur Geschichte und Anat. des Pankreas*, Basel, 1893) and W. M. Baldwin (' The Pancreatic Ducts in Man,' *The Anatomical Record*, vol. v., May 1911).

Varieties of the pancreas and its ducts.—One of the most interesting, but rare, variations in the form of the pancreas, is the condition known as the annular pancreas. The duodenum, usually its descending part, is surrounded by a ring of pancreatic tissue continuous with the head of the gland. It generally causes a constriction of the duodenum at the situation of this ring, with dilations above and below (Symington, ' Notes on a Rare Abnormality of the Pancreas,

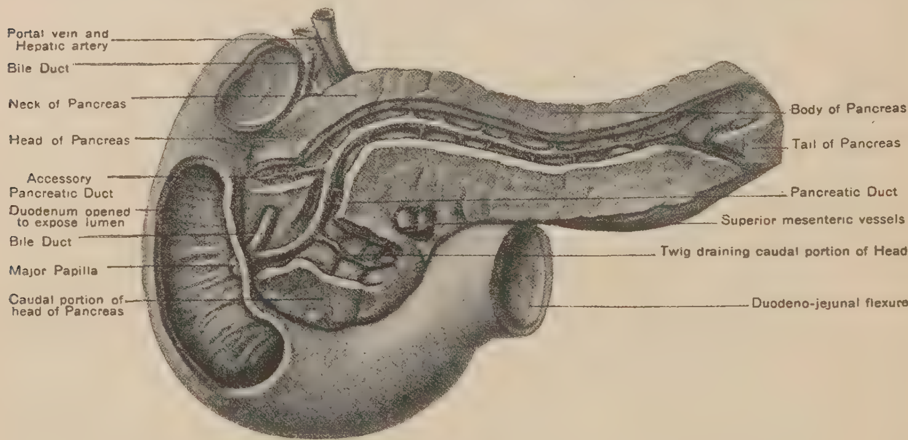


FIG. 143.—DUODENUM AND PANCREAS VIEWED FROM THE FRONT. (W. M. Baldwin.)

A portion of the pancreas has been removed to expose its ducts.

Jour. Anat. and Phys., vol. xix., 1885). Various attempts have been made to explain the mode of production of this variation (see W. M. Baldwin, ' A Specimen of Annular Pancreas,' *Anatomical Record*, vol. iv., August 1910; and Lecco, ' Zur Morphologie des Pancreas annulare,' *Sitz. d. k. Akad. d. Wissensch. in Wien*, 1910; and Elizabeth Cords, ' Ein Fall von ringformigen Pancreas nebst Bemerkungen ueber die Genese dieser Anomalie,' *Anat. Anzeiger*, Bd. xxxix., 1911). It is generally admitted that the ventral rudiment of the pancreas consists of a right and a left part. The left usually atrophies, but it may persist, or the right half may exhibit excessive growth and surround the pancreas. The duct contained in the ring joins the ductus pancreaticus near the duodenum. The tail of the pancreas is sometimes bifid; and the part of the head lying behind the mesenteric vessels may be separate from the remainder of the gland, and form what is called the *lesser pancreas*.

Various examples of an accessory pancreas have been described. They occur most frequently in the wall of the upper part of the jejunum; more rarely, in the wall of the stomach or of the ileum. They are generally situated either in the submucous or the subserous coat, but may extend amongst the muscular fibres. The size of these masses varies in diameter, from a few millimetres to four or five centimetres. Their appearance in the wall of the intestine is a repetition of a normal condition in some of the lower vertebrata. In a few cases, some pancreatic tissue has been found at the blind end of intestinal diverticula (see Zenker, ' Nebenpancreas in der Darmwand,' *Arch. f. path. Anat.*, Bd. xxi.; Glinski, ' Zur Kenntniss des Nebenpancreas und verwandter Zustände,' *Arch. f. path. Anat.*, Bd. clxiv; Reitman, ' Zwei Fälle von accessorischen Pancreas,' *Anat. Anzeiger*, Bd. xxiii.).

Peculiarities in the infant.—By the time of birth, the pancreas has acquired its adult position and shape, but, owing to the relatively large size of the supra-renal gland at this period, as compared with the kidney, the left gland may extend downwards sufficiently far on the kidney to separate the pancreas entirely from contact with this organ. Its length at birth is about 3·5 cm. (Ballantyne).

Structure.—The pancreas has no well-defined fibrous capsule, but is invested by loose areolar tissue, and the peritoneum which covers it can be readily detached from the gland. It belongs to the class of acino-tubular glands. In its general characters it closely resembles the salivary glands, but it is somewhat looser and softer in its texture than those organs, the lobes and lobules being less compactly arranged.

Blood-vessels, lymphatics, and nerves.—The **arteries** of the pancreas are derived from the *splenic* and *hepatic divisions of the cœliac axis*, and from the *inferior pancreatico-duodenal branch of the superior mesenteric*. Its **veins** are tributaries of the *splenic* and *superior mesenteric*, and therefore belong to the portal system. The **lymphatic** vessels of the pancreas pass to various groups of glands, which are not only connected with the pancreas but also with some of the neighbouring abdominal organs—such as the stomach, spleen, left supra-renal gland, liver, and duodenum. Their arrangement within the pancreas is similar to that found in the salivary glands.

The **nerves** are derived from the cœliac plexus, and accompany the arteries to the organ. They are almost exclusively non-medullated, and have minute ganglia on them as they traverse the gland. Besides these ganglia, small cells—apparently of nervous nature—are found upon the nerves, near their distribution to the epithelium-cells of the alveoli, over and between which they ultimately ramify.

RESPIRATORY SYSTEM.

The organs of respiration and voice (*apparatus respiratorius*) comprise the *larynx*, *trachea*, and *bronchi*; and the *lungs*, with their serous investments, named the *pleuræ*. They also include the nasal cavities (described in Vol. III. Pt. II., in connexion with the organs of sense) and the upper part of the pharynx.

The pharynx, the upper part of which serves as a respiratory passage, has already been described in this part of Vol. II.

The respiratory organs are developed as a median outgrowth from the ventral wall of the fore-gut, and this primitive connexion between the alimentary canal and the respiratory apparatus is maintained in the adult, the upper end of the air-passage opening on the anterior wall of the pharynx. Below, this median air-tube divides into two lateral branches, one for each lung, while its upper part is modified to form the organ of voice. In the majority of mammals, the larynx opens into the nasal part of the pharynx, the ventral boundary of the orifice (the epiglottis), projecting forwards behind the soft palate. This is not the case, however, in the human subject, either during intra-uterine or extra-uterine life.

LARYNX.

The **larynx** is placed at the upper and fore-part of the neck, where it forms a considerable prominence in the middle line. It lies between the large vessels of the neck, and is suspended from the tongue and hyoid bone. It is covered in front by the skin and cervical fascia along the middle line, and on each side also by the sterno-hyoid, omo-hyoid, sterno-thyroid, and thyro-hyoid muscles, by the upper end of the lateral lobe of the thyroid gland, and by a small part of the inferior constrictor of the pharynx. Behind, it is separated from the fourth, fifth, and sixth cervical vertebræ by the laryngeal part of the pharynx and the prevertebral muscles. Above, it opens into the cavity of the pharynx, and below, into that of the trachea (fig. 54).

Its dimensions, according to Sappey, are, on an average of eight males and eight females, as follows :—

Vertical diameter, measured from the upper border of the thyroid cartilage to the lower border of the cricoid, 44 mm. in the male and 36 mm. in the female.

Transverse diameter, represented by the distance between the posterior borders of the thyroid cartilage, 43 mm. in the male and 41 mm. in the female.

Antero-posterior diameter, measured from the most prominent part of the anterior border of the thyroid cartilage to a line uniting its posterior borders, 36 mm. in the male and 26 mm. in the female.

The larynx consists of a framework of cartilages, articulated together, and connected by elastic membranes or ligaments, two of which, projecting towards the interior of the cavity, are named the *plicæ vocales*, being more immediately

concerned in the production of the voice. It possesses special muscles, which move the cartilages one upon another, and modify its form and the tension of its ligaments. It is lined by a mucous membrane, continuous above with the mucous membrane of the pharynx, and below with that of the trachea.

CARTILAGINES LARYNGIS.

The cartilages of the larynx consist of three single and symmetrical pieces, named respectively the *thyroid cartilage*, the *cricoid cartilage*, and the *cartilage of the epiglottis*; and of three pairs, namely—the *arytenoid cartilages*, the *corniculate*

Fig. 144.—Front view of the laryngeal cartilages and ligaments. (Sappey.)

1, hyoid bone; 2, its large cornua; 3, its small cornua; 4, thyroid cartilage; 5, thyro-hyoid membrane; 6, lateral thyro-hyoid ligament, containing the *cartilago triticea*, 7; 8, cricoid cartilage; 9, crico-thyroid membrane; 10, lateral cerato-cricoid ligaments 11, uppermost ring of trachea.

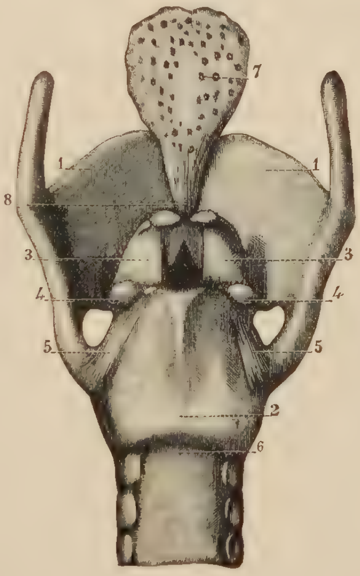


Fig. 145.—Back view of the laryngeal cartilages and ligaments. (Sappey.)

1, thyroid cartilage; 2, cricoid cartilage; 3, arytenoid cartilages; 4, their muscular processes; 5, a ligament better marked than usual, connecting the lower cornu of the thyroid with the back of the cricoid cartilage; 6, upper ring of the trachea; 7, epiglottis; 8, ligament connecting it to the angle of the thyroid cartilage. The cartilagines corniculatæ are seen surmounting the arytenoid cartilages.

cartilages [Santorini], and the *cuneiform cartilages* [Wrisbergi]. In all, there are nine distinct pieces, but the corniculate and cuneiform cartilages are very small. Only the thyroid and cricoid cartilages are visible on the front and sides of the larynx; the back of the cricoid cartilage, surmounted by the arytenoid cartilages, and these again by the corniculate, are seen behind; whilst the epiglottis is situated in front of, and cuneiform cartilages on each side of, the upper opening.

The **thyroid,** which is the largest of the laryngeal cartilages, consists of two flat lateral plates (lamina dextra and lamina sinistra), which are united in front at the isthmus, and form an angle of about 90° with one another in the male, and 120° in the female. This angular projection is subcutaneous, most prominent at the upper part, and is much more marked in the male than in the female, being named in the former the **pomum Adami** (*prominentia laryngea*).

The two symmetrical halves, called the laminæ, are somewhat quadrilateral in form. Of each half, the anterior border is the shortest; the superior border of the isthmus being surmounted by a deep *thyroid notch* (see fig. 144). The free posterior border is thickened and vertical, and is prolonged upwards and downwards into two processes or *cornua*; it gives attachment to the stylo-pharyngeus and palato-pharyngeus muscles. The upper and lower borders have each a well-marked concavity close to the cornu; otherwise, the upper is convex and the lower nearly straight. The flattened lateral surface of each lamina is marked by an indistinct oblique line or ridge (fig. 144), which, commencing above at the posterior part of the superior border, in a slight prominence called the *superior tubercle*, passes downwards and slightly forwards and ends at the lower border in an *inferior tubercle*, so as to mark off the anterior three-fourths of the surface from the remainder. This line gives attachment below to the sterno-thyroid, and above to the thyro-hyoid muscle; whilst the small smooth surface behind it gives origin to part of the inferior constrictor of the pharynx, and affords attachment, by means of areolar tissue, to the thyroid body. On their median surfaces, the laminæ are smooth and slightly concave. At or close to the receding angle, are attached, from above downwards, the epiglottis, the ventricular and vocal folds, and, slightly farther out, the thyro-arytenoidei muscles. Below, and in front, the median surface of the thyroid cartilage forms part of the lateral wall of the larynx; while above and behind, it is covered by the mucous membrane of the pharynx (see figs. 156 and 157). Of the four cornua, all of which bend inwards, the two *superior* or *great* cornua (fig. 145) pass upwards, with sometimes a slight backward curve, and terminate each in a blunt extremity which is connected, by means of the lateral thyro-hyoid ligament, to the tip of the corresponding great cornu of the hyoid bone (fig. 144, 2). The *inferior* or *smaller* cornua, which are somewhat thicker, but shorter, are directed slightly forwards, and, on the inner aspect of the tip, show a smooth surface for articulation with a prominence on the side of the cricoid cartilage.

Occasionally, there is a foramen in the lamina of the thyroid cartilage, situated near the upper part of its posterior border; an abnormal branch of the superior laryngeal artery passes through it. In the infant, the isthmus of the thyroid cartilage differs from the two laminæ in being less opaque and more flexible.

The **cricoid cartilage** (figs. 144, 8 and 152, 2), which is shaped like a signet-ring, is thicker and stronger than the thyroid. It is deep behind, where it is expanded into a squarish plate or *lamina*, measuring in the male about 25 mm. from above downwards; but in front it is shallow, having a vertical measurement of only 8 mm. The *superior border*, which is markedly elevated behind, passes downwards and forwards to end anteriorly below the thyroid cartilage; while the *inferior border* is horizontal, and connected by fibrous tissue to the first ring of the trachea. The posterior elevated part of the upper border is slightly depressed towards the middle line, and at the sides of this depression are the elongated oval facets for articulation with the arytenoid cartilages. These facets are cylindrically curved, and they look outwards as well as upwards. The convex aspect of the ring of cartilage is smooth in front and at the sides, where it affords attachment to the crico-thyroid muscles, and behind these to the inferior constrictors of the pharynx, while posteriorly it presents a vertical median ridge, to which some of the longitudinal fibres of the œsophagus are attached. On each side of this ridge is a broad depression, occupied by the posterior crico-arytenoid muscle; lateral to which is a small, flat, oval and slightly raised surface for articulation with the inferior cornu of the thyroid cartilage. The concave inner surface of the ring is covered

throughout by the mucous membrane of the larynx. At its lower border, the cricoid is circular, but, higher up, the cartilage is somewhat compressed laterally, so that the passage through it is here elliptical.

The **arytenoid cartilages** (fig. 145, 3) are two in number, and symmetrical in form and position. They may be compared in shape to irregular three-sided pyramids, and they rest by their bases on the posterior and highest part of the cricoid cartilage, while their somewhat curved apices approach one another. Each is about 20 mm. high and 10 mm. broad at the base. Of the three faces, the *posterior* is broad, triangular, and concave from above downwards, lodging part of the arytenoid muscle. The *antero-lateral surface* has a transverse ridge (*crista arcuata*), situated about the junction of its lower and middle thirds; above and below this, the surface is concave. The lower concavity (*fovea oblongata*) gives attachment to the thyro-arytenoideus and the lateral crico-arytenoid muscles; the upper (*fovea triangularis*) gives attachment to the *ligamentum ventricularis* of the *plica ventricularis*, and is also closely related to a quantity of glandular tissue. The *median* surface is the narrowest of the three; indeed, in its upper half it is reduced to a narrow border, is nearly parallel to that of the opposite cartilage, and is covered below by the laryngeal mucous membrane.

The *base* of each arytenoid cartilage is slightly hollowed, having towards its outer part a smooth concave surface for articulation with the cricoid cartilage. Two of its angles are remarkably prominent: namely—one lateral, short and rounded, which projects backwards and outwards, and into which the posterior and the lateral crico-arytenoid muscles are inserted (*processus muscularis*); the other *anterior*, which is more pointed, and forms a horizontal projection, to which the corresponding vocal ligament is attached (*processus vocalis*).

The *apex* curves backwards and a little inwards, and terminates in a blunt point, which is surmounted by the corniculate cartilage.

A small cartilaginous nodule (sesamoid cartilage) is sometimes found at the outer side of the arytenoid, near the tip, embedded in the perichondrium.

The **corniculate cartilages** [Santorini] are two small yellowish cartilaginous nodules of a somewhat conical shape, which are articulated with the summits of the arytenoid cartilages (fig. 145), and serve, as it were, to prolong them backwards and inwards. They sometimes form part of the arytenoid cartilages.

The **cuneiform cartilages** [Wrisbergi] are two very small, oblong, yellowish, cartilaginous bodies, placed one on each side towards the posterior part of the fold of the mucous membrane (*plica aryepiglottica*), which extends from the summit of the arytenoid cartilage to the epiglottis. They occasion small elevations of the mucous membrane, a little in advance of the cornicula, with which, however, they are not directly connected.

According to Goeppert ('Ueber die Herkunft des Wrisbergischen Knorpels,' *Morph. Jahrbuch.*, Bd. xxi., 1894), these cartilages are primarily lateral processes of the epiglottis, which may become detached from this cartilage and secondarily united with the arytenoids. In some mammals, the epiglottis, the cuneiform and the arytenoid cartilages form a ring surrounding the laryngeal aperture. The cuneiform cartilages are sometimes absent.

The **epiglottis** (fig. 145, 7) is a median lamella of yellow fibro-cartilage, shaped somewhat like an obovate leaf, and covered by mucous membrane. It is placed in front of the superior opening of the larynx, projecting, in the ordinary condition, upwards immediately behind the base of the tongue.

The cartilage of the epiglottis is broad and rounded at its upper free margin, but below it becomes pointed, and is prolonged by means of a narrow, elastic band (the *thyro-epiglottic ligament*) to the deep angular depression between the laminæ

of the thyroid cartilage, to which it is attached behind and just below the median notch. Its *lateral* borders, which are convex and turned backwards, are only partly free, the lower parts being enveloped in the aryepiglottic folds of mucous membrane. The *anterior* or *lingual* surface is free only in its upper part, where it is covered by mucous membrane. Lower down, the membrane is reflected from it forwards to the base of the tongue, forming three folds—the median, and the two lateral *glosso-epiglottic plicæ*. This surface is also connected below with the posterior surface of the hyoid bone by a median elastic structure named the *hyo-epiglottic ligament*. The *posterior* or *laryngeal* surface, which is free in the whole of its extent, presents from above downwards two convexities, with an intermediate concavity. The lower convexity, projecting backwards into the laryngeal cavity, is named the *tuberculum epiglotticum*. The epiglottis is closely covered by mucous membrane, on removing which, the yellow cartilaginous lamella is seen to be pierced by numerous little pits and perforations, in which are lodged small glands, which open on the surface of the mucous membrane.

Minute additional laryngeal cartilages are sometimes present. An *inter-arytenoid* or *pre-cricoid* occurs regularly in some animals, but is rare in man, as are also the sesamoid cartilages found on the lateral aspects of the arytenoid cartilages.

Structure of the cartilages of the larynx.—The epiglottis, the corniculate, and the cuneiform cartilages are composed of elastic or yellow fibro-cartilage, and have no tendency to ossify. The apices of the arytenoid cartilages are also formed of elastic fibro-cartilage, but the greater part of these, as well as the cricoid and thyroid cartilage, are composed of hyaline cartilage, resembling generally that of the costal cartilages, like which, they are very prone to ossification as life advances.

Peculiarities of the larynx according to age and sex.—In the fetus the larynx is considerably higher, in relation to the vertebral column, than in the adult. Thus, in the sixth month of fetal life, the upper end of the epiglottis is opposite the anterior arch of the atlas, and the lower border of the cricoid cartilage is at the level of the middle of the body of the fourth cervical, the whole larynx being thus fully two vertebræ higher than in adult life. Until puberty, the larynx gradually descends, by which time it has attained its adult position. This descent of the larynx is, therefore, independent of the special increase in size of the organ occurring at puberty, and appears to be associated with the growth in a vertical direction of the facial part of the skull, which is relatively very small in the fetus, and with the subsidence in early life of the thoracic viscera (see J. Symington, 'On the Relations of the Larynx and Trachea to the Vertebral Column in the Fetus and Child,' *Jour. Anat. and Phys.*, vol. xix., 1885).

Up to the age of puberty, the larynx is similar in the male and female; the chief characteristics at that period being the small size and comparative slightness of the organ, and the smooth rounded form of the thyroid cartilage in front. In the female, these conditions are permanent, excepting that a slight increase in size takes place. In the male, on the contrary, at the time of puberty, remarkable changes rapidly occur, and the larynx becomes more prominent and more perceptible at the upper part of the neck. Its cartilages become larger, thicker, and stronger, and the laminæ of the thyroid cartilage project forwards in front so as to form at their union with one another the prominent ridge of the *pomum Adami*. At the same time, the median notch on its upper border is considerably deepened. In consequence of these changes in the thyroid cartilage, the distance between its angle in front and the arytenoid cartilages behind becomes greater, and the vocal ligaments are necessarily lengthened. Hence the dimensions of the glottis, which, at

the time of puberty, undergo an increase of about one-third only in the female, are nearly doubled in the male, and the adult male larynx becomes altogether one-third larger than that of the female.

Taguchi[1] found that the average distance from the upper border of the thyroid cartilage to the lower border of the cricoid, measured in the median plane, was in thirty-nine males 4·8 cm. and in thirty-three females 3·8 cm.

Ossification of the cartilages of the larynx.—At about twenty years of age, ossification usually begins in the thyroid and cricoid cartilages, and a few years later in the arytenoids. In the thyroid cartilage, ossification takes place first near the inferior cornu, and this is speedily followed by the appearance of a median nucleus in the angle between the laminæ; from the lower cornu the ossification extends along the inferior and posterior borders, and thence spreads through the lamina. The cricoid cartilage first becomes ossified at its upper border on each side, near the

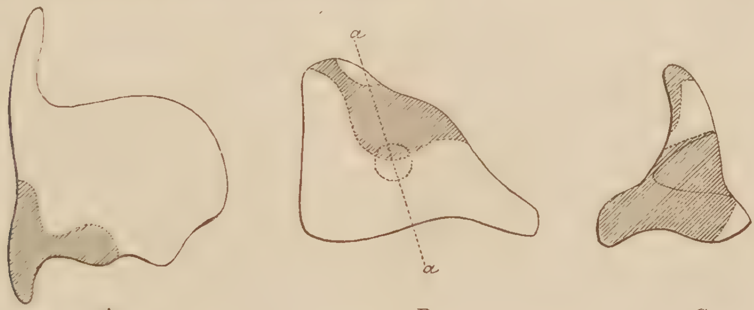


FIG. 146.—VIEWS OF THYROID, CRICOID, AND ARYTENOID CARTILAGES PARTIALLY OSSIFIED
Portion ossified shaded. (Chievitz.)

The relative proportions of the three cartilages are not kept in this figure.

A, thyroid cartilage, with inferior cornu and adjacent part of lamina ossified; B, cricoid cartilage ossified at upper part; C, arytenoid almost completely ossified.

arytenoid and thyroid articular facets, and the bony masses of the two sides soon become united across the back of the ring; the lower border remains cartilaginous for some time longer. The arytenoid cartilages become ossified from below upwards. The ossification begins somewhat earlier, and proceeds more rapidly in the male than in the female (J. H. Chievitz, *Arch. f. Anat.*, 1882; and M. Schleier, *Arch. de Lary.*, 1898).

MORPHOLOGY OF THE CARTILAGES OF THE LARYNX.

The cricoid and the arytenoids are the most primitive of the laryngeal cartilages, being found in connexion with the air-passages of certain of the amphibia, and also in the reptilia; while the thyroid and the epiglottis—at least in a well-developed condition—are peculiar to mammals. The cricoid cartilage is derived from the upper part of the cartilaginous framework of the trachea. In some mammals (marsupials) it blends in front with the thyroid cartilage. The arytenoid cartilages may represent the two lateral elements of a tracheal ring. In marsupials, these two cartilages articulate with one another at their base. The thyroid cartilage represents the ventral portions of the skeleton of two pairs of visceral arches (fourth and fifth), with probably one or two median pieces or copulæ. In the ornithorhynchus, these five parts of the thyroid can be recognised as distinct elements, but in the higher mammalia they are more or less blended. In man, the two cornua of each lamina represent ununited parts of the two arches; while the peculiarities in appearance and structure of the isthmus, as compared with the lamina, indicate the median portion uniting the arches. Both Nicolas and Kallius have shown that the thyroid cartilage is developed as a paired structure; and in each lateral half, according to Kallius, cartilage first appears in two places—one near the cranial and the other at the caudal border. According to Dubois, the epiglottis represents a chondrification in the submucosa of the glosso-laryngeal fold, the cartilages of Wrisberg being formed in a similar manner in the ventricular folds. Gegenbaur maintains, however, that the epiglottis is an independent element of the skeleton, derived from the fourth pair of visceral arches, and according to Goeppert, the cartilages of Wrisberg

[1] 'Beiträge zur topographischen Anatomie des Kehlkopfes,' *Arch. f. Anat.*, 1889.

are formed from the lateral processes of the primitive epiglottis. There is no evidence that the epiglottis was primitively a paired structure, and it is probably not derived from a visceral arch. One or two cartilaginous elements are often found between the arytenoid cartilages (inter-arytenoid) in mammals, and are sometimes met with in man. For literature, consult Dubois, 'Zur Morphologie des Larynx,' *Anat. Anzeiger*, 1886; Gegenbaur, *Die Epiglottis*, 1892; Symington, 'The Marsupial Larynx,' *Jour. Anat. and Phys.*, vol. xxxiii., and 'The Cartilages of the Monotreme Larynx,' *ibid.*, vol. xxxiv.; Goeppert, 'Ueber die Herkunft des Wrisbergischen Knorpels,' *Morph. Jahrbuch*, Bd. xxi., 1894; Nicolas, 'Recherches sur le développement de quelques éléments du larynx humain,' *Bibliog. Anat.*, 1894; Kallius, 'Beiträge zur Entwickelungsgeschichte des Kehlkopfes,' *Anat. Hefte*, Bd. ix., 1897; and J. Schaffer, 'Zur Histologie, Histogenese und phylogenetischen Bedeutung der Epiglottis,' *Anat. Hefte*, Heft 101, 1907.

LIGAMENTS AND JOINTS OF THE LARYNX.

The continuous layer of fibrous tissue, uniting the thyroid cartilage with the hyoid bone, is described as consisting of a median hyo-thyroid ligament, and on each side of this of a hyo-thyroid membrane and a lateral hyo-thyroid ligament. The *ligamentum hyo-thyroideum medium* is attached below to the notch on the upper border of the thyroid cartilage, and, above, to the upper part of the posterior surface of the body of the hyoid bone. Owing to this arrangement, the thyroid cartilage, when drawn upwards, readily slips within the circumference of the hyoid bone. Behind this ligament is the epiglottis, with the mucous membrane of the base of the tongue, separated, however, by adipose tissue and mucous glands. The *membrana hyo-thyroidea* connects the lateral part of the lamina of the thyroid cartilage with the great cornu of the hyoid bone. This membrane is thin and loose, and is perforated by the superior laryngeal vessels and the internal branch of the superior laryngeal nerve. The *ligamentum hyo-thyroideum laterale*, placed at the posterior limit of the hyo-thyroid membrane, is a round yellowish cord, which passes up from the tip of the superior cornu of the thyroid cartilage to the posterior extremity of the great cornu of the hyoid bone. It frequently encloses a small oblong cartilaginous nodule, which is named *cartilago triticea*; sometimes this nodule is bony.

In front of the median hyo-thyroid ligament are two bursæ; one of these is large, and extends from behind the body of the hyoid bone downwards to the notch on the thyroid cartilage, the other, small and not constant, lies in the concavity on the posterior aspect of the hyoid bone and in front of the upper end of the larger sac (Clermont, 'Les bourses muqueuses prélaryngées,' *Bibliog. anat.*, t. xv., 1906).

The thyroid and cricoid cartilages are connected by a membranous ligament and the capsules of a pair of synovial articulations.

The **crico-thyroid membrane** (fig. 144, 9) is divisible into a median and two lateral portions. The median or anterior portion, broad below and narrow above, is a strong, triangular, yellowish ligament, consisting chiefly of elastic tissue, and is attached below to the upper border of the anterior arch of the cricoid cartilage, and, above, to the median part of the lower border of the thyroid cartilage. Its anterior surface is convex, is partly covered by the crico-thyroid muscles, and is crossed horizontally by a small anastomotic arterial arch, formed by the junction of the crico-thyroid branches of the right and left superior thyroid arteries. The lateral portions are fixed below on each side along the inner edge of the upper border of the cricoid, and, passing upwards in relation to the mucous membrane of the larynx, terminate above by becoming continuous with the inferior thyro-arytenoid ligaments. The whole of the crico-thyroid membrane, with the last-named ligaments, is sometimes termed the *conus elasticus* (His).

The **crico-thyroid articulations**, between the inferior cornua of the thyroid cartilage and the lateral aspects of the cricoid, are two small but distinct joints, having each a ligamentous capsule and a synovial membrane. The prominent oval articular surfaces of the cricoid cartilage are directed upwards and outwards, while those of the thyroid cartilage look in the opposite direction. The capsule is strengthened by several small fibrous bundles, known as the cerato-cricoid ligaments. The movement allowed is of a rotatory description, the axis of rotation passing transversely through the two joints. In addition, a slight gliding movement, forwards and backwards, may occur.

Ligaments of the epiglottis.—The blunt apex of the epiglottis (*petiolus epiglottidis*) is connected with the upper part of the receding angle of the thyroid cartilage by the thyro-epiglottic ligament. The median and two lateral folds of mucous membrane extending from the front of the epiglottis to the tongue contain some ligamentous fibres (median and lateral glosso-epiglottic ligaments). A rather strong band of fibres passes from the upper border of the body of the hyoid bone horizontally backwards to the front of the epiglottis, forming the hyo-epiglottic ligament. Below this, is a space bounded in front by the median thyro-hyoid ligament, and behind by the epiglottis, and extending laterally between the thyro-hyoid membrane and the mucous membrane of the pharynx (see E. Saint-Martin, 'Région glosso-thyro-épiglottique,' *Comptes Rendus de l'Association des Anatomistes*, 1911).

The ligamenta ventriculares consist of a few slight elastic fasciculi, contained within the folds of mucous membrane, forming the *plicæ ventriculares* (hereafter to be described), and are fixed in front to the angle between the laminæ of the thyroid cartilage, somewhat above its middle, and close to the attachment of the epiglottis; behind, they are connected to the inner part of the fovea triangularis on the antero-lateral surface of the arytenoid cartilages. They are continuous above with scattered elastic bundles, which reach upwards into the aryepiglottic folds, and, forwards, to the sides of the epiglottis. This layer of elastic fibres forms on each side the *membrana quadrangularis*.

The **ligamenta vocales** are formed of fine closely arranged elastic fibres, which are attached in front to the middle of the angle between the alæ of the thyroid cartilage, and behind to the vocal processes of the arytenoid cartilages. The inner edge of each ligament is free and sharply defined between these attachments, and, covered by the mucous membrane, forms the plica vocalis. In other directions these ligaments are less sharply defined, for, in their outer part, they spread out both above and below as they pass backwards. Below, the vocal ligament passes in continuity with the cerato-cricoid ligament, so that it may be described as an upward extension of this ligament; and the vocal ligament may be stated to be formed by the superior free edge of the crico-thyroid membrane.

The **crico-arytenoid articulations**, like the crico-thyroid, are typical diarthrodial joints, each having a capsular ligament, and a synovial membrane and cavity. The articular surface on the cricoid has its long axis directed from above outwards and downwards, and a vertical section of the joint in this axis shows the two opposing surfaces of the cricoid and arytenoid to be flat. The surface on the cricoid is convex from before backwards and outwards, and the arytenoid shows a corresponding concavity. From the shape of the opposing surfaces, the joint may be described as cylindrical. The articular surface on the cricoid is a little larger than that on the arytenoid, and there is a small meniscus at the posterior part of the joint. The capsule is thin and lax, except behind, where it is strengthened by a posterior crico-arytenoid ligament. The movements of the joint are free,

and consist of (*a*) a movement round the long axis of the joint, so that the vocal process of the arytenoid is turned inwards and downwards (flexion), or upwards and outwards (extension); (*b*) a gliding movement of the arytenoid, upwards and inwards, or downwards and outwards; and (*c*) a rotation of the arytenoid on its long axis, by which the vocal process is turned inwards or outwards. It is at this joint that the movements occur by which the vocal folds are separated or approximated and rendered lax, the tension of the vocal folds being produced by a movement of the crico-thyroid joints.[1]

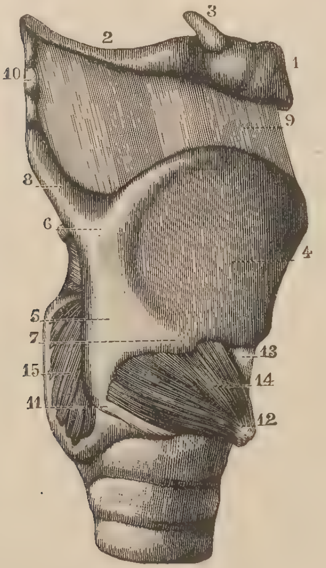


FIG. 147.—MUSCLES OF THE LARYNX, AS SHOWN IN A VIEW OF THE LARYNX FROM THE RIGHT SIDE. (Sappey.)

1, hyoid bone; 2, 3, its cornua; 4, right lamina of thyroid cartilage; 5, posterior part of the same separated by oblique line from anterior part; 6, 7, superior and inferior tubercles, at ends of oblique line; 8, upper cornu of thyroid; 9, thyro-hyoid ligament; 10, cartilago triticea; 11, lower cornu of thyroid, articulating with the cricoid; 12, anterior part of cricoid; 13, crico-thyroid membrane; 14, crico-thyroid muscle; 15, posterior crico-arytenoid muscle, partly hidden by thyroid cartilage.

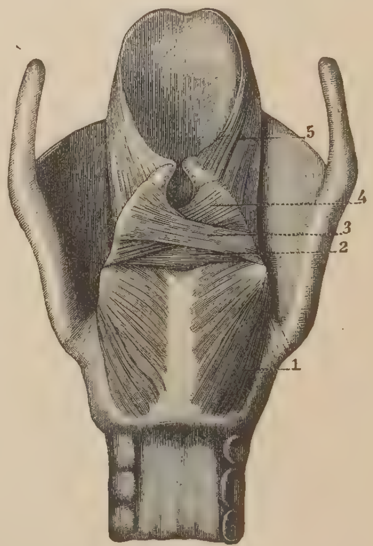


FIG. 148.—MUSCLES OF THE LARYNX AS SEEN IN A VIEW OF THE LARYNX FORM BEHIND. (Sappey.)

1, posterior crico-arytenoid; 2, arytenoid muscle; 3, 4, oblique fibres passing around the edge of the arytenoid cartilage, some of which join the thyro-arytenoid, and others form (5) the aryepiglottic.

MUSCLES OF THE LARYNX.

Besides certain extrinsic muscles elsewhere described—namely, the sterno-hyoid, omo-hyoid, sterno-thyroid, and thyro-hyoid muscles, together with the muscles of the supra-hyoid region, the middle and inferior constrictors of the pharynx, and the stylo-pharyngeus and palato-pharyngeus, all of which act more or less upon the entire larynx—there are other muscles which move the different cartilages upon one another, and modify the size of the aperture in the larynx (the rima glottidis) and the state of tension of the vocal ligaments bounding the anterior part of the rima glottidis.

These intrinsic muscles are the *crico-thyroid*, the *posterior crico-arytenoid*, the *lateral crico-arytenoid*, the *thyro-arytenoid*, the *arytenoid*, and the *aryepiglottic*,

[1] For further particulars regarding this joint, consult E. Will, 'Ueber die Articulatio crico-arytenoidea,' *Inaug. Dissertation*, Königsberg, 1895; and Charpy and Clermont, 'L'articulation crico-aryténoidienne et les cylindroses,' *Comptes Rendus de l'Association des Anatomistes*, 1906.

together with certain other slender muscular fasciculi. All these muscles, except the arytenoid which crosses the middle line, are in pairs.

The **crico-thyroid muscle** (fig. 147, 14) is a short, thick, triangular muscle seen on the front of the larynx. Its attachment below to the cricoid cartilage extends from the median line a considerable way backwards, and its fibres passing upwards and outwards, and diverging slightly, are fixed above to the inferior border of the thyroid cartilage, and to the anterior border of its lower cornu. The latter portion of the muscle, the fibres of which are nearly horizontal, is usually distinct from the rest. Some of the superficial fibres are almost always continuous with the inferior constrictor of the pharynx. The muscles of the two sides are separated from one another in the middle line in front, leaving a small interval, which is triangular, with the base upwards. The crico-thyroid membrane is here exposed.

Action.—The anterior part of the muscle contracting will approximate the cricoid and thyroid cartilages in front. In this action, the thyroid is fixed by the extrinsic muscles; and the anterior part of the cricoid, rotating on the axis which unites the articulations between the cricoid and the lower cornua of the thyroid is drawn upwards, and the part behind the crico-thyroid joints is depressed, and with it the arytenoid cartilages, so that the vocal ligaments are thus put on the stretch. This stretching of the vocal ligaments is still further assisted by the action of the oblique fibres, which, acting from the cornu of the fixed thyroid, draw the cricoid cartilage backwards. It is found, also, that with electric excitation of this muscle the anterior part of the cricoid is raised towards the thyroid. Paralysis of these muscles is accompanied by inability to produce high notes.

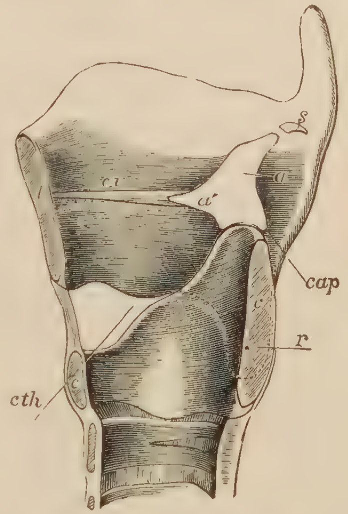


Fig. 149.—Outline of the right half of the cartilages of the larynx as seen from the median aspect, with the vocal ligament, to illustrate the action of the crico-thyroid muscle. (Allen Thomson.)

t, thyroid cartilage; *c*, cricoid cartilage; *a*, right arytenoid cartilage; *a′*, its vocal process; *s*, corniculate cartilage; *c v*, vocal ligament; the position of the lower cornu of the thyroid cartilage on the outside of the cricoid is indicated by a dotted outline, and *r* indicates the point or axis of rotation of the cricoid on the cornu of the thyroid; *c t h*, a line in the principal direction of action of the crico-thyroid muscle; *c a p*, the same of the posterior crico-arytenoid muscle.

The **posterior crico-arytenoid muscle** (fig. 148, 1), situated behind, arises from the broad depression on the corresponding half of the posterior surface of the cricoid cartilage, and its fibres, converging upwards and outwards, are inserted into the muscular process of the arytenoid cartilage, behind the attachment of the lateral crico-arytenoid muscle. The upper fibres are short, and almost horizontal; the middle are the longest, and run obliquely; whilst the lower or external fibres are nearly vertical. Near their insertion, the upper fibres are blended with the lower fibres of the arytenoideus.

Action.—The posterior crico-arytenoid muscles draw the outer angles of the arytenoid cartilages backwards and inwards, and thus rotate the anterior or vocal processes outwards, and widen the rima glottidis. Acting with the lateral crico-arytenoid muscles, they approximate the vocal cords (Kanthack). They may also draw the arytenoid cartilages apart. They come into action during deep inspiration. If paralysed, the lips of the glottis approach the middle line, and come in contact during each inspiration, so that severe dyspnœa may be produced. Expiratory efforts, however, are not impeded, and vocalisation is unaffected.

Variety.—In connexion with the posterior crico-arytenoid muscle may be mentioned an occasional small slip in contact with its lower border—namely, the **cerato-cricoid** muscle of Merkel. It is a short and slender bundle, arising from the cricoid cartilage near its lower border,

a little behind the inferior cornu of the thyroid cartilage, and passing obliquely outwards and upwards to be inserted into that process. It usually exists on one side only. Turner found it in seven out of thirty-two bodies. It is not known to be of any physiological significance (Merkel, *Anat. und Phys. des menschl. Stimm- und Spräch-organs*, Leipzig, 1857; Turner, in *Month. Med. Journal*, February 1860).

The **lateral crico-arytenoid muscle** (fig. 150, *cr.ar.lat.*), smaller than the posterior, is in a great measure hidden by the lamina of the thyroid cartilage. It lies along the sloping upper border of the cricoid cartilage, from which it arises, its origin extending as far back as the articular surface for the arytenoid. Its fibres pass backwards and upwards, the anterior or upper ones being necessarily the longest, and they are attached to the muscular process of the arytenoid cartilage and to the adjacent part of its anterior surface.

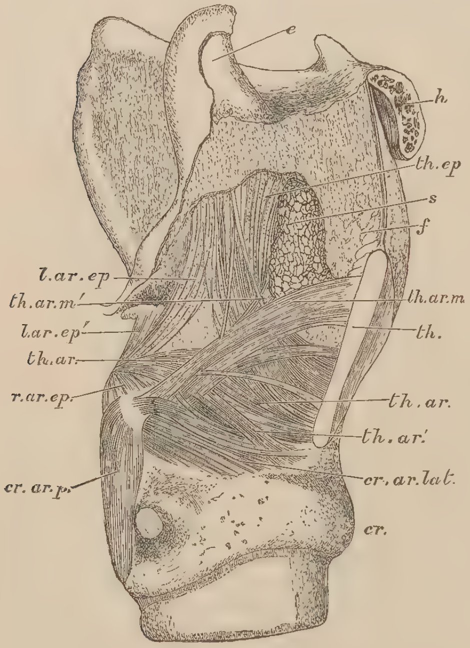


FIG. 150.—SIDE VIEW OF THE LARYNX AFTER REMOVAL OF THE RIGHT LAMINA OF THE THYROID CARTILAGE. (S. G. Shattock.)

h, body of hyoid bone, cut; *e*, epiglottis; *th*, cut surface of right lamina of thyroid cartilage; *cr*, front of cricoid cartilage, the articular facet for the inferior cornu of the thyroid is seen posteriorly; *th.ar*, *th.ar*, fibres of the thyro-arytenoid (outer portion) passing from the thyroid in front to the arytenoid behind; *th.ar'*, others arising from the crico-thyroid membrane; another considerable mass of fibres is seen arising from the same parts, and passing at first obliquely and afterwards nearly vertically upwards as the thyro-epiglottic muscles, *th.ep.*; *th.ar.m*, small thyro-arytenoid; *th.ar.m'*, a small slip of the same muscle passing into the ventricular fold; *cr.ar.lat*, lateral crico-arytenoid; *cr.ar.p*, posterior crico-arytenoid; *r.ar.ep*, right aryepiglottic muscle near its origin; *l.ar.ep*, left aryepiglottic near its insertion; *l.ar.ep'*, portion of the same inserted into the cornicula; *f.*, fat; *s*, appendix covered by mucous glands.

This muscle is covered internally by the lateral part of the crico-thyroid membrane, and externally at its anterior part by the upper part of the crico-thyroid muscle. The upper part is in close contact, and, indeed, is always more or less blended with the thyro-arytenoid, and a few of its fibres are continuous round the outer side of the arytenoid cartilage with the arytenoideus muscle.

Action.—These muscles, drawing the muscular processes of the arytenoids forwards and downwards, rotate the vocal processes inwards, and approximate the plicæ vocales. They thus act antagonistically to the posterior crico-arytenoids.

If both posterior and lateral crico-arytenoids be thrown into action simultaneously, the arytenoids will not undergo rotation, but will be drawn inwards, and the rima glottidis will thus be narrowed.

The **thyro-arytenoid muscle** (fig. 150)—Under this name is often included a mass of muscular tissue which, although containing bundles of muscular fibres differing in position, attachments, and function, does not admit on dissection of separation into completely independent muscles. The mass may, however, be conveniently subdivided into the musculus vocalis, the musculus thyro-arytenoideus, and the musculus ventricularis. The *musculus vocalis* is often described as the musculus thyro-arytenoideus internus. It appears, on coronal section, as a triangular bundle,

projecting towards the cavity of the larynx just lateral to the vocal ligament. The fibres arise from the thyroid cartilage external to the vocal ligament, and also from a small yellow nodule (*macula flava,* or cartilage of Luschka) in the anterior part of this ligament; and are inserted into the front and lateral aspects of the vocal process of the arytenoid cartilage. Some of the innermost fibres are described by some anatomists as arising from the vocal ligament and passing backwards to the vocal process.

The *musculus thyro-arytenoideus* lies laterally to the vocal muscle, and is often termed the lateral thyro-arytenoid. Its fibres arise from the thyroid cartilage, close to the origin of the internal portion, and from the crico-thyroid membrane; from here, they in part pass backwards to be inserted into the lateral border and muscular process of the arytenoid cartilage. The *musculus ventricularis* consists of scattered bundles of oblique fibres, which arise from the thyroid cartilage above the muscles just described, and pass upwards and backwards into the plica ventricularis.

Action.—The bundles of the thyro-arytenoid muscle, differing as they do in direction and in points of attachment, must differ also in their action, if separately called into play. The antero-posterior fibres will tend to draw forwards the arytenoid, and with it the posterior part of the cricoid cartilage, rotating the latter upwards, and antagonising the action of the crico-thyroid, the effect being to relax the vocal ligament. But if the latter be kept stretched and approximated by the action of other muscles, those fibres of the inner portion which are in close contact with the vocal ligament may serve to modify its elasticity and consistence, while the fibres which constitute the portio ary-vocalis may serve, as Ludwig has pointed out, to tighten the parts of the cord in front of their attachment, and to slacken the parts behind. The vertical fibres

FIG. 151.—A CORONAL SECTION OF PART OF THE LARYNX PASSING THROUGH THE MIDDLE THIRD OF THE GLOTTIS. Magnified eight diameters. (W. L. H. Duckworth.)

C.T., thyroid cartilage; C.C.R., cricoid cartilage; M.V., musculus vocalis; M.T.A., musculus thyro-arytenoideus; M.C.A.L., musculus crico-arytenoideus lateralis; M.C.T., musculus crico-thyroideus; M., muscular fibres in plica ventricularis; LG. VN., ligamentum ventriculare; C.EL., conus elasticus; GL., glands in plica ventricularis. The area of the mucous membrane between the two arrows above and below the glottis is covered with stratified squamous epithelium.

of the muscle which extend from the sloping part of the crico-thyroid membrane across the base of the vocal fold, and over the ventricle into the plica ventricularis, must, when they contract, render the free edge more prominent. Finally, the fibres which are inserted into the muscular process and outer surface of the arytenoid will tend to draw forwards and rotate inwards the arytenoid cartilage, and those which pass up into the aryepiglottic folds may assist in depressing the epiglottis.

If the thyro-arytenoid muscles are paralysed, the lips of the glottis are no longer parallel, but are curved with the concavity towards one another, and a much stronger blast of air is required for the production of the voice.

Santorini described three thyro-arytenoid muscles: an *inferior*, a *middle*, and a *superior*. The latter is not always present. The inferior thyro-arytenoid muscle of Santorini comprises most of the antero-posterior bundles; the middle thyro-arytenoid, the oblique bundles of the external portion. The fibres of the superior fasciculus, when present, arise nearest to the notch of the thyroid cartilage, and are attached to the upper part of the base of the arytenoid cartilage (fig. 150, *th.arm.*). This is named by Sœmmering the *small* thyro-arytenoid, whilst the two other portions of the muscle constitute the *great* thyro-arytenoid of that author.

Arytenoideus muscle.—When the mucous membrane is removed from the back of the arytenoid cartilages, a thick band of transverse fibres is laid bare (fig. 148, 2), and on the dorsal surface of this are seen two slender decussating oblique bundles (3, 4).

The transverse and oblique fibres are often described as separate muscles (arytenoid and aryepiglottic), but the two sets of fibres are intimately blended. Most of the anterior or ventral fibres pass straight across between the arytenoid cartilages, and are attached to about the outer half of the concave surface on the back of each. The dorsal fibres can be traced into the lateral walls of the larynx, the uppermost fibres to the cartilages of Santorini, the intermediate fibres run partly independently and partly with the uppermost fibres of the thyro-arytenoidei into the inner and outer walls of the appendices of the larynx, forming the so-called aryepiglottic muscles, and the lowest fibres blend at the level of the vocal folds with the thyro-arytenoid and lateral crico-arytenoid muscles.

Action.—The *arytenoid* muscle draws the arytenoid cartilages together, and, from the structure of the crico-arytenoid joints, this approximation, when complete, is necessarily accompanied by depression. If the muscle is paralysed, the intercartilaginous part of the glottis remains patent, although the membranous lips can still be approximated.

The superior aperture of the larynx has been generally supposed to be closed during the act of deglutition by the descent of the upper free end of the epiglottis as a lid over the opening. From observations made by Stuart and McCormack (' The Position of the Epiglottis in Swallowing,' *Jour. Anat. and Phys.*, vol. xxvi.), it has been shown that this is not the case: the epiglottis projecting upwards in close contact with the base of the tongue. According to Stuart (' On the Mechanism of the Closure of the Larynx,' *Proc. Roy. Soc. London*, 1892), it is effected by the two arytenoid cartilages being drawn together and also forwards, so that their upper ends are brought in contact with the posterior surface of the epiglottis. These movements of the arytenoid cartilages are produced by the contraction of the arytenoid and thyro-arytenoid muscles.

It is remarked by Henle that the muscles 'which lie in the space enclosed by the laminæ of the thyroid cartilage, and above the cricoid, may be regarded in their totality as a kind of sphincter, such as is found in its simplest form embracing the entrance of the larynx in reptiles.' In the human larynx, there is a marked predominance of adductor over abductor fibres (acting upon the vocal folds).

CAVUM LARYNGIS.

Cavum laryngis.—The cavity of the larynx is divided into an upper and a lower compartment by the aperture of the glottis or *rima glottidis*, consisting of an anterior *pars intermembranacea* and a posterior *pars intercartilaginea*. The lateral margins of the *pars intermembranacea* are formed by the plicæ vocales, and the *pars intercartilaginea* by the vocal processes and by the inner aspects of the

bases of the arytenoid cartilages (see fig. 157). The upper compartment consists of the vestibule, which extends from the aditus to the rima vestibuli, or aperture between the plicæ ventricularis, and, below this rima, of a cavity which extends on each side into a lateral recess or *ventriculus laryngis*, bounded above by the plica ventricularis and below by the plica vocalis. From the ventricle, a blind pouch extends upwards, lateral to the plica ventricularis, called the

FIG. 152.—MEDIAN SECTION OF THE LARYNX AND THE UPPER PART OF THE TRACHEA, WITH A VIEW OF THE INTERIOR OF THEIR RIGHT HALVES. (Sappey.)

1, ventricle; 2, plica ventricularis, and 3, plica vocalis; 4, arytenoid cartilage covered with mucous membrane; 5, arytenoid muscle cut across; 6, slope of crico-thyroid membrane leading up to ligamentum vocale; 7, 8, sections of cricoid; 9, its upper border; 9′, its lower border; 10, section of thyroid; 11, upper part of larynx; 12, 13, glandular prominence in aryepiglottic fold; 14, 16, epiglottis; 15, fat between it and the thyro-hyoid membrane; 17, section of epiglottis; 18, section of hyoid bone; 19, 20, trachea.

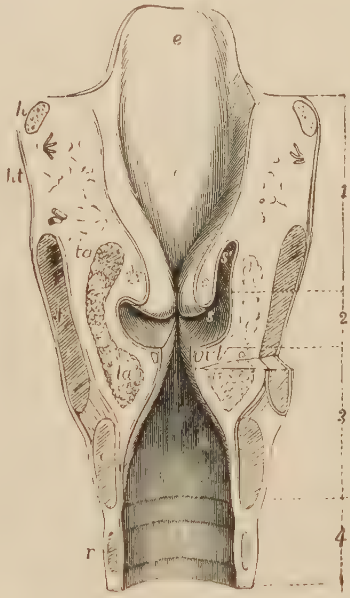


FIG. 153.—ANTERIOR HALF OF A CORONAL SECTION THROUGH THE LARYNX NEAR ITS MIDDLE. (Allen Thomson.)

1, upper division of the laryngeal cavity; 2, central portion; 3, lower division, continued into 4, trachea; *e*, the free part of the epiglottis; *e′*, its cushion; *h*, great cornu of the hyoid bone; *ht*, thyro-hyoid membrane; *t*, thyroid cartilage; *c*, cricoid cartilage; *r*, first ring of the trachea; *ta*, thyro-arytenoid muscle; *vl*, inferior thyro-arytenoid ligament in the plica vocalis; *s*, the ventricle; above this, the plica ventricularis; *s′*, the appendix ventriculi opened on the right side by carrying the section farther forward.

appendix ventriculi laryngis. The lower compartment passes inferiorly into the cavity of the trachea without any constriction between them. The whole of the larynx is lined with mucous membrane.

The **aditus laryngis,** or superior aperture of the larynx, when open, is triangular, wide in front and narrow behind, the lateral margins sloping obliquely downwards and backwards. It is bounded in front by the free upper border of the epiglottis (fig. 154, *A*, *e*, and fig. 155, *a*); behind, by the summits of the arytenoid cartilages (fig. 154, *B*, *a*) and corniculatæ (*s*), with the angular border of mucous membrane crossing the median space between them, and on the sides by two folds

of mucous membrane, the *aryepiglottic folds*, which, enclosing a few ligamentous and muscular fibres and the cuneiform cartilages (fig. 154, *B*, *w*), pass forwards from the tips of the arytenoid cartilages and corniculatæ to the lateral margins of the epiglottis (fig. 155, 8, 9, 10).

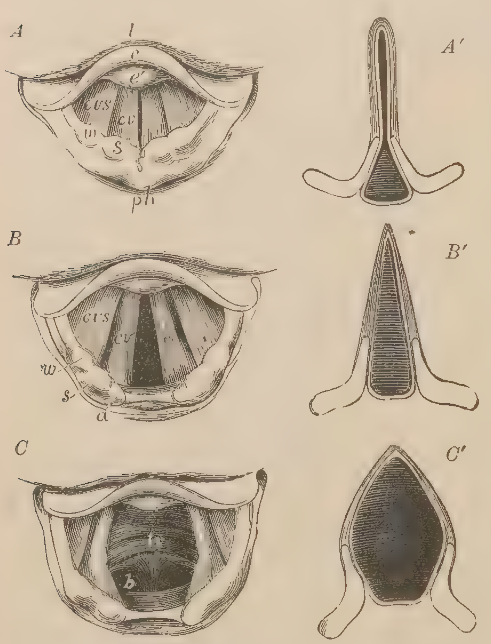


FIG 154.—THREE LARYNGOSCOPIC VIEWS OF THE SUPERIOR APERTURE OF THE LARYNX AND SURROUNDING PARTS IN DIFFERENT STATES OF THE GLOTTIS DURING LIFE. (Czermak.)

A, the glottis during the emission of a high note in singing. *B*, in easy or quiet inhalation of air. *C*, in the state of widest possible dilatation, as in inhaling a very deep breath. The diagrams *A′*, *B′*, *C′*, have been added to Czermak's figures to show, in horizontal sections of the glottis, the position of the vocal ligaments and arytenoid cartilages in the three several states represented in the other figures. In all the figures, so far as marked, the letters indicate the parts as follows, viz.: *l*, the base of the tongue; *e*, the upper free part of the epiglottis; *e′*, the tubercle or cushion of the epiglottis; *p h*, part of the anterior wall of the pharynx behind the larynx; in the margin of the aryepiglottic fold, *w*, the swelling of the membrane caused by the cuneiform cartilage; *s*, that of the corniculum; *a*, the tip of the arytenoid cartilages; *c v*, the plicæ vocales; *c v s*, the plicæ ventriculares; between them the ventricle of the larynx; in *C*, *t r* is placed on the anterior wall of the receding trachea, and *b* indicates the commencement of the two bronchi beyond the bifurcation, which may be brought into view in this state of extreme dilatation.

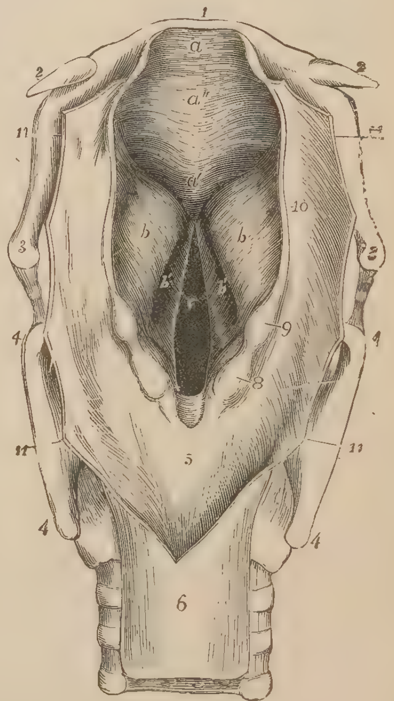


FIG. 155.—PERSPECTIVE VIEW OF THE PHARYNGEAL OPENING INTO THE LARYNX FROM ABOVE AND BEHIND. (Allen Thomson.)

The superior aperture has been much dilated; the glottis is in a moderately dilated condition; the wall of the pharynx is opened from behind and turned to the sides. 1, body of the hyoid bone; 2, small cornua; 3, great cornua; 4, cornua of the thyroid cartilage; 5, membrane of the pharynx covering the posterior surface of the cricoid cartilage; 6, gullet; 7, trachea; 8, projection caused by the cartilage of Santorini; 9, the same belonging to the cartilage of Wrisberg; 10, aryepiglottic fold; 11, cut margin of the wall of the pharynx; *a*, free part of the epiglottis; *a′*, its lower pointed part; *a″*, the cushion; *b*, eminence on each side over the appendix of the larynx; *b′*, the ventricles; *c*, the rima glottidis; the lines on each side point to the plicæ vocales.

When the superior aperture is closed during the act of deglutition, it presents, according to Anderson Stuart and McCormack,[1] a T-shaped fissure. The transverse limb of the T is slightly curved, with the convexity forwards, and is bounded in front by the epiglottis, and behind by the aryepiglottic folds. The vertical limb

[1] 'The Position of the Epiglottis in Swallowing,' *Jour. Anat. and Phys.*, vol. xxvi., 1892.

of the T is represented by a median fissure, extending from the epiglottis in front to the inter-arytenoid fold behind, and bounded at the sides by the arytenoid cartilages.

Vestibulum laryngis.—The anterior wall of the vestibule is formed by the epiglottis, and, in conformity with the shape of this cartilage, it is triangular with the apex below; a groove on each side indicates the position of the lateral margin of the cartilage. The lateral walls extend from the plicæ aryepiglotticæ to the plicæ ventriculares, and contain the appendices of the ventricles. In the low posterior wall are the upper parts of the arytenoid cartilages and the inter-arytenoid fold.

The **plicæ ventriculares**—also called the false vocal cords, because they are not immediately concerned in the production of the voice—are rounded folds of mucous membrane extending, one on each side of the rima vestibuli, from the thyroid to the arytenoid cartilages, and containing some elastic tissue (ligamenta ventricularia), mucous glands, and muscular fibres. They form somewhat arched projections immediately above the corresponding ventricle. The latter is seen on looking down into the laryngeal cavity, the plicæ ventriculares being farther apart than the plicæ vocales.

Wylie showed (*Edin. Med. Journal*, 1866) that when the plicæ ventriculares are simply approximated, and air is injected into the larynx from below, they prevent the exit of the air, and he held that the closure of the glottis in defæcation and vomiting is mainly effected by their apposition. His experiments have been confirmed by Brunton and Cash.

The **glottis** is the tongue-like projection towards the cavity of the larynx, which is specially concerned in the production of voice. On coronal section (fig. 151), it is seen to form a triangular mass, with a free upper surface forming the floor of the ventricle, a free sloping median surface looking inwards and downwards, and a lateral, nearly vertical, attached boundary. The mucous membrane covering the angle between the upper and the inner surface is the plica vocalis, the elastic ligament immediately adjacent, the *ligamentum vocale*, and the muscular fibres just external to the ligament, the *musculus vocalis*. The mucous membrane covering the ligamentum vocale is so thin and closely adherent as to show the yellowish colour of the ligament through it. Near its anterior extremity, the plica shows a slight swelling—due to the nodule of elastic tissue, described by Luschka—and another prominence marks the position of the apex of the processus vocalis.

Taguchi[1] gave the following data for the determination of the position of the plicæ vocales and plicæ ventriculares in relation to the anterior aspect of the thyroid cartilage. The plicæ vocales are attached to the thyroid cartilage, close to one another: in the male 8·5 mm., and in the female 6·5 mm., below the bottom of the median notch on the upper border of the thyroid cartilage. The plicæ ventriculares are 4 mm. apart at their anterior attachment, and 2·5 mm. higher than the plicæ vocales (see fig. 158).

The **rima glottidis**, an elongated aperture, situated anteriorly, between the plicæ vocales (pars intermembranacea), and posteriorly, between the bases of the arytenoid cartilages (pars intercartilaginea), varies in its size and shape according to the position of its lateral boundaries. In phonation, the part between the vocal folds is a long narrow slit, while that bounded by the arytenoid cartilages forms a small triangular aperture (fig. 154, *A′*). When moderately open, as in easy respiration, its shape is that of a long triangle, the pointed extremity being directed forwards, and the base being behind, between the arytenoid cartilages (fig. 154, *B′*); in its fully dilated condition, as in deep inspiration, it is lozenge-shaped (the posterior

[1] 'Beiträge zur topographischen Anatomie des Kehlkopfes,' *Arch. f. Anat.*, 1889.

sides being formed by the inner sides of the bases of the arytenoid cartilages), while the posterior angle is truncated (c′). The rima glottidis is the narrowest part of the interior of the larynx; in the adult male it measures about 23 mm., or nearly an inch, in an antero-posterior direction, and 6 mm. or 8 mm. across at its widest part, which may be dilated to nearly 12 mm. In the female, and in males before the age of puberty, its dimensions are less: its antero-posterior diameter being about 17 mm. and its transverse diameter about 4 mm. The vocal folds are about 15 mm. long in the adult male and 11 mm. in the female.

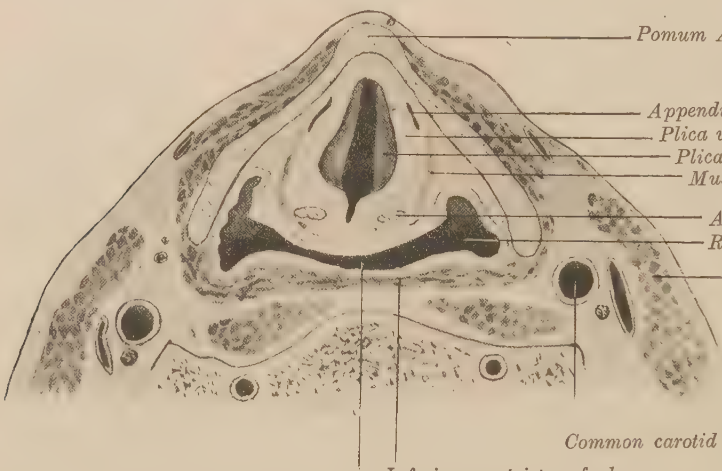


FIG. 156.—HORIZONTAL SECTION OF THE LARYNX, PHARYNX, ETC., OF AN ADULT MALE. Natural size. (J. Symington.)

The larnyx is divided near the upper part of the laminæ of the thyroid cartilage and opposite the plicæ ventriculares.

Ventriculi laryngis.—The ventricles of the larynx are lateral recesses, one on each side, extending outwards between the ventricular and vocal folds. Each ventricle is of a somewhat oval form with the long axis horizontal; it begins just behind the isthmus of the thyroid cartilage and reaches backwards to the front of the arytenoid cartilage. The lateral wall of the ventricle is separated from the lamina of the thyroid cartilage by some fibres of the thyro-arytenoideus muscle.

The *appendices* of the ventricles (figs. 153 and 156) lead from the anterior part of the ventricles upwards, for the space of half an inch, between the ventricular folds and the thyroid cartilage, reaching as high as the upper border of that cartilage, and nearly to the level of the aryepiglottic folds. The pouch, which is of variable size, is conical in shape, and curved slightly backwards. Its opening into the ventricle is narrow, and is generally marked by two folds of the lining mucous membrane. Numerous small mucous glands, sixty or seventy in number, open into its interior, and it is surrounded by a quantity of fat, and by a fibrous investment, which is continuous with the ventricular ligament.

The upper fibres of the thyro-arytenoid muscles pass over the outer side of the pouch, a few being attached to its lower part. The appendix is supplied abundantly with nerves, derived from the superior laryngeal.

The appendix of the ventricle may extend beyond the upper border of the lamina of the thyroid cartilage, turn outwards through the thyro-hyoid membrane, and appear on the lateral aspect of the larynx. Such cases are comparatively rare. The first definite record of this abnormality appears to have been made by Bennet ('Malformation of the Larynx,' *Quar.*

Jour. Medical Science, 1865). Subsequently, Gruber (*Arch. f. Anat.*, 1874; and *Beobachtungen aus d. mensch. u. vergleich. Anatomie*, 1879) reported several cases. Sclavunas ('Ueber die Ventricularsäcke des Kehlkopfes beim erwachsenen und neugeborenen Menschen sowie bei

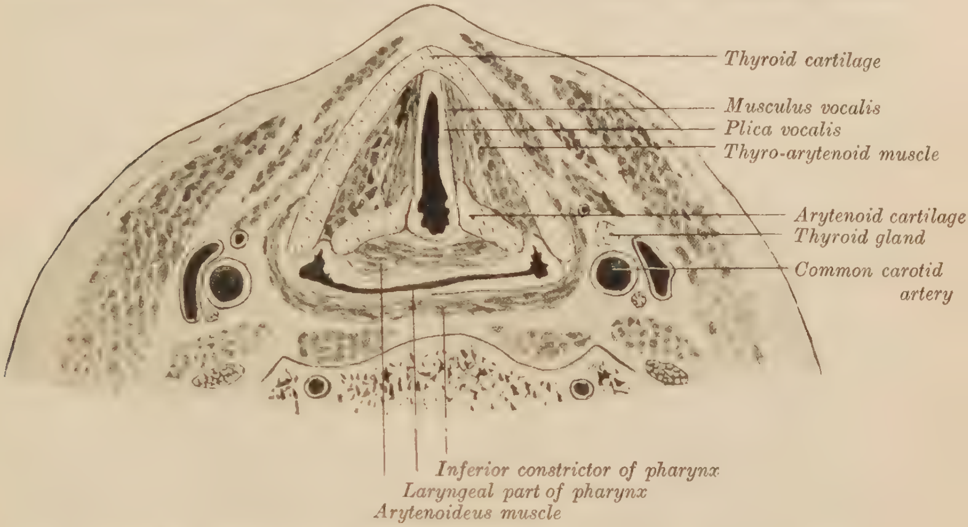


FIG. 157.—HORIZONTAL SECTION OF THE LARYNX, PHARYNX, ETC., OF AN ADULT MALE. Natural size. (J. Symington.)

The larynx is divided towards the lower part of the laminæ of the thyroid cartilage and opposite the plicæ vocales.

einigen Affen,' *Anat. Anzeiger*, Bd. xxiv.; 1904) has collected reports of ten cases, to which he has added three observed by himself. Such extra-laryngeal extensions of the ventricular appendices are normal in many apes, and may attain a very large size, extending down the neck over the clavicle and between the two heads of the great pectoral muscle into the axilla. This great air-sac may be connected with one appendix only, although it extends down both sides of the median plane. The blind end of the appendix sometimes passes upwards, lateral to the aryepiglottic fold, and behind the body of the hyoid bone, so as to lie close to the floor of the glosso-epiglottic fossa.

The part of the laryngeal cavity below the rima glottidis is markedly compressed from side to side at its upper end, owing to the prominence of the glottis; but it gradually expands, and, opposite the ring of the cricoid, is nearly circular. It terminates opposite the lower border of the cricoid cartilage by becoming continuous with the lumen of the trachea.

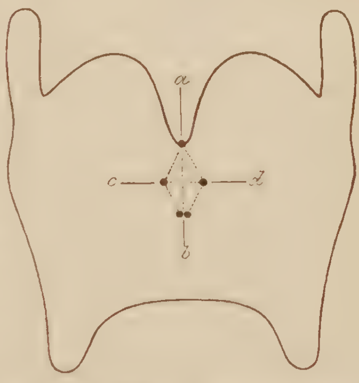


FIG. 158.—ANTERIOR ASPECT OF THYROID CARTILAGE TO SHOW POINTS OPPOSITE WHICH THE VOCAL AND VENTRICULAR LIGAMENTS ARE ATTACHED. (Taguchi.)

a, bottom of thyroid notch; *c* and *d'* opposite attachment of the ventricular folds; *b*, opposite attachment of the vocal folds.

A. Gerlach[1] made a series of experiments on the cadaver to ascertain the influence of the contraction of the intrinsic muscles of the larynx upon the size of the laryngeal cavity. He found that the greatest diminution of the cavity was produced by a simultaneous contraction of the crico-thyroids, the lateral crico-arytenoids, and arytenoid muscles; and the greatest increase by the contraction of the two posterior crico-arytenoids. Contraction of the crico-thyroids and the lateral crico-arytenoids effected the greatest narrowing of the rima glottidis, and the rima was most fully opened by the action of the posterior crico-arytenoids and the arytenoid muscles.

[1] 'Zur Anatomie des Cavum laryngis des Menschen,' *Anatomische Hefte*, Heft xlvi., 1900.

THE MUCOUS MEMBRANE, VESSELS, AND NERVES OF THE LARYNX.

The laryngeal **mucous membrane** is thin and of a pale colour. In some situations it adheres intimately to the subjacent parts—especially on the epiglottis, and still more in passing over the vocal folds, on which it is very thin and most closely adherent. About the upper part of the larynx, above the glottis, it is extremely sensitive. In and near the aryepiglottic folds, it covers a quantity of loose areolar tissue, which is liable in disease to infiltration, constituting œdema of the glottis. Like the mucous membrane in the rest of the air-passages, that of the larynx is covered in the greater part of its extent with a columnar ciliated epithelium, by the vibratory action of which, the mucus is urged upwards; but over the vocal folds it is provided with stratified squamous epithelium. In the submucous tissue there are numerous *glands* which secrete an abundant mucus, and the orifices of which may be seen almost everywhere, excepting upon and near the plicæ vocales. They abound particularly upon the epiglottis—in the substance of which are found upwards of fifty small compound glands, some of them perforating the cartilage. Between the anterior surface of the epiglottis, the hyoid bone, and the root of the tongue is a mass of yellowish fat, erroneously named the epiglottic gland, in or upon which some small glands may exist. Another collection of glands is placed within the fold of mucous membrane in front of each arytenoid cartilage, from which a series may be traced forwards, along the corresponding ventricular fold. The glands of the laryngeal pouches have already been noticed.

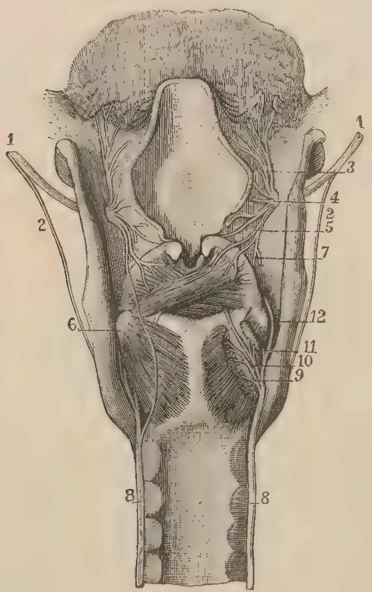


Fig. 159.—Posterior view of the nerves of the larynx. (Sappey.)

1, superior laryngeal nerve; 2, its external branch; 3, 4, 5, branches to the mucous membrane of the larynx; 6, filaments uniting the left superior and inferior laryngeal nerves; 7, the same on the right side, cut; 8, 8, inferior laryngeal nerves; 9, branch to the posterior crico-arytenoid muscles; 10, branch to the arytenoid; 11, 12, branches passing to the lateral crico-arytenoid and the thyro-arytenoid muscles.

Blood-vessels, lymphatics, and nerves of the larynx.—The **arteries** of the larynx are derived from the *superior thyroid* (a branch of the external carotid), and from the *inferior thyroid* (a branch of the subclavian). The **veins** join the *superior, middle,* and *inferior thyroid* veins.

The **lymphatics** of the larynx are divisible into an upper and a lower set: the line of separation between the two being the plicæ vocales, in which the lymphatic network is very feebly developed. The upper set is very abundant in the ventricular folds, the walls of the ventricles and their appendices, and the posterior surface of the epiglottis. Three to six afferent vessels on each side pierce the corresponding thyro-hyoid membrane in close relation to the superior thyroid vessels, and pass to deep cervical glands situated near the bifurcation of the common carotid artery. A few small afferent vessels from the lower set of lymphatics pierce the crico-thyroid membrane, and end in one or two small glands often found in front of that membrane, or pass to some pre-tracheal glands; but the larger afferent vessels

issue from the larynx below the cricoid cartilage, and end in glands on the side of the trachea.

The **nerves** are the superior and inferior largyneal branches of the vagi, joined by filaments of the sympathetic. The internal branch of the superior larygneal is sensory to the mucous membrane, and contains also the vaso-motor and secretory

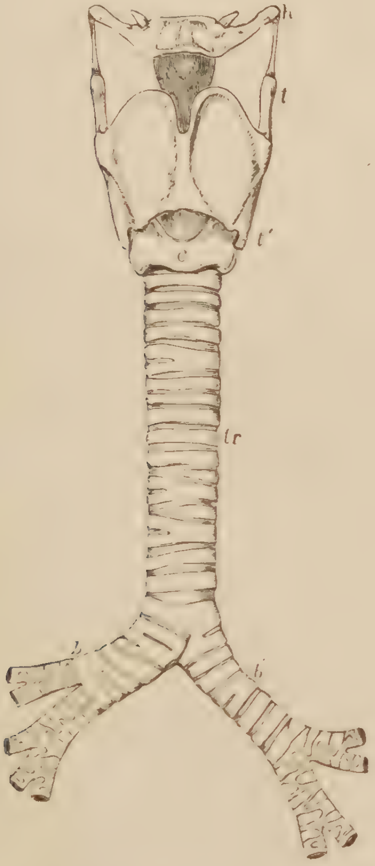


FIG. 160.—OUTLINE SHOWING THE GENERAL FORM OF THE LARYNX, TRACHEA, AND BRONCHI, AS SEEN FROM BEFORE. One-third natural size. (Allen Thomson.)

h, the great cornu of the hyoid bone; *e*, epiglottis; *t*, superior, and *t′*, inferior cornu of the thyroid cartilage; *c*, middle of the cricoid cartilage; *t r*, the trachea, showing sixteen cartilaginous rings; *b*, the right, and *b′*, the left bronchus. In this, and also in the succeeding figure, the right bronchus is represented as somewhat more horizontal than is usually described.

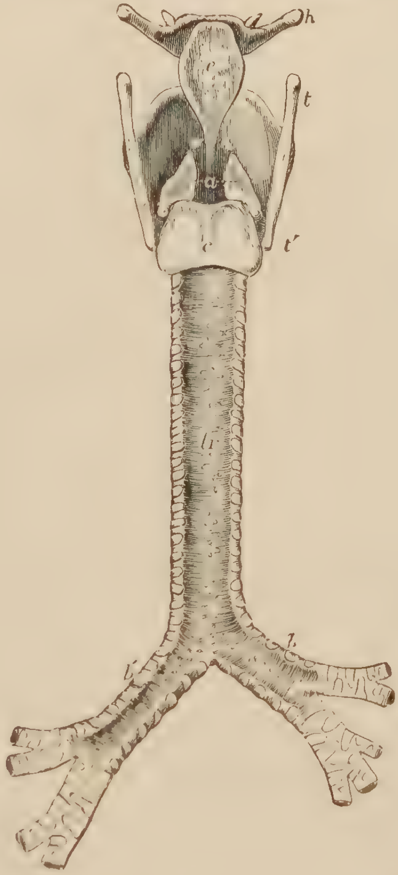


FIG. 161.—OUTLINE SHOWING THE GENERAL FORM OF THE LARYNX, TRACHEA, AND BRONCHI, AS SEEN FROM BEHIND. One-half natural size. (Allen Thomson.)

h, great cornu of the hyoid bone; *t*, superior, and *t′*, inferior cornu of the thyroid cartilage; *e*, the epiglottis; *a*, points to the back of both the arytenoid cartilages, which are surmounted by the cornicula; *c*, the middle ridge on the back of the cricoid cartilage; *t r*, the posterior membranous part of the trachea; *b*, *b′*, right and left bronchi.

fibres, while the external branch supplies the crico-thyroid muscle. The inferior laryngeal nerve supplies all the intrinsic muscles of the larynx, except the crico-thyroid, so that it is the motor nerve to both the adductor and abductor muscles of the vocal cord. In progressive organic lesions of this nerve, the fibres going to the abductor muscles are first involved. The cause of this greater vulnerability of the abductors is not known.

THE TRACHEA AND TWO MAIN BRONCHI.

The **trachea** is that part of the common air-passage of both lungs which commences above at the larynx, and divides below into two smaller tubes, right and left bronchi, one for each lung (figs. 160 to 163).

Position.—The trachea has a median position in the neck and thorax, and extends from the lower border of the cricoid cartilage of the larynx, on a level with the lower part of the sixth, or upper part of the seventh, cervical vertebra, into the upper part of the thorax, where it is crossed in front and on the left side by the arch of the aorta, and then bifurcates into the two bronchi at about the level of the disk between the fourth and fifth thoracic vertebræ. As the trachea passes obliquely downwards and somewhat backwards, it gradually recedes from the anterior surface of the neck in its course towards the thorax. At its commencement it can readily be felt through the skin, while at its termination it lies, on an average, about 3 cm. to 4 cm. posterior to the front of the sternum.

FIG. 162.—HORIZONTAL SECTION OF TRACHEA, ŒSOPHAGUS AND THYROID BODY. Natural size. (J. Symington.)

1, œsophagus; 2, cavity of trachea; 3, cartilaginous ring of trachea; 4, thyroid body; 5, inferior thyroid artery; 6, inferior laryngeal nerve.

Size.—It usually measures, in the erect position of the head, from 9 cm. to 11 cm. in length; but its length may be increased 2 cm. to 3 cm. by over-extension of the neck and decreased by flexion.

It is usually stated, on the authority of Aeby, that the trachea gradually increases in calibre from above downwards; but according to Braune and Stahel,[1] it presents a series of alternate dilatations and contractions. Thus it is smallest at its commencement; from this point it gradually increases, until about midway between its two ends; from here it diminishes to within about 3 cm. of its bifurcation, towards which it again enlarges. Its average diameter is about 18 mm. in the male and 15 mm. in the female. In front and at the sides, the trachea is rendered cylindrical, firm, and resistant, by a series of cartilaginous rings; these, however, are deficient behind, so that the posterior portion is flattened and entirely membranous (fig. 162). Near its bifurcation, the trachea is somewhat expanded laterally.

Relations of the trachea to neighbouring parts.—The windpipe is nearly everywhere invested by a loose areolar tissue, abounding in elastic fibres, and is very movable on the surrounding parts. Both in the neck and thorax, it rests behind against the gullet, which intervenes between it and the vertebral column; but towards its lower part it projects somewhat to the left side. The inferior laryngeal nerve ascends to the larynx on each side in the angle between these two tubes.

In the neck, the trachea is situated between the common carotid arteries; at its upper end it is embraced by the lateral lobes of the thyroid body, the middle part or isthmus of which lies across it just below the larynx. It is covered in front by the sterno-thyroid and sterno-hyoid muscles, between which, however, there is left an elongated lozenge-shaped interval in the middle line: this interval is covered in by a strong process of the deep cervical fascia, while, more superficially, another layer, not so strong, crosses between the sterno-mastoid muscles. The

[1] 'Ueber das Verhältniss der Lungen zu den Bronchen,' *Arch. f. Anat.*, 1888.

inferior thyroid veins and the *arteria thyroidea ima*, when that vessel exists, also lie upon its anterior surface below the isthmus of the thyroid body; while just above the level of the upper edge of the sternum the innominate artery is occasionally found crossing obliquely in front of it.

In the thorax, the trachea is covered by the manubrium sterni, together with the sterno-thyroid and sterno-hyoid muscles and the remains of the thymus gland; behind these, by the left innominate vein, then by the commencement of the innominate artery and left carotid, which pass round to its sides; and lastly, by the arch of the aorta and the deep cardiac plexus of nerves. Placed between the two pleuræ, the trachea is contained in the superior mediastinum, and has near

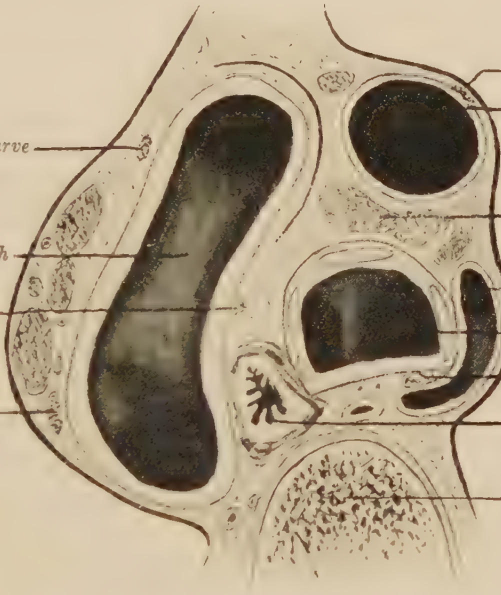


FIG. 163.—HORIZONTAL SECTION OF THE ŒSOPHAGUS, TRACHEA, AORTIC ARCH, ETC., AT THE LEVEL OF THE FIFTH THORACIC VERTEBRA, VIEWED FROM ABOVE. Natural size. (J. Symington.)

its right side the right lung, separated, however, by the pleura and the vagus nerve. On the left side, the arch of the aorta, the left common carotid and subclavian arteries, and the left inferior laryngeal nerve, together with some cardiac nerves, intervene between it and the left lung and pleura. The pulsations of the aorta are transmitted to the lower part of the left wall of the trachea, and can be seen in the living body with the bronchoscope (Eichen, *Brit. Med. Jour.*, November 19, 1910).

The **right and left bronchi** (figs. 160 and 161, *b*, *b′*) proceed each to the root of the corresponding lung, and then undergo division. Previous to this, they exactly resemble the trachea on a smaller scale, being rounded and firm in front and at the sides, where they are provided with imperfect cartilaginous rings, and flattened and membranous behind. The right bronchus is larger than the left; the area of a section at right angles to the long axis of the right bronchus being in the proportion of 100 to 78 for a corresponding section of the left bronchus. It is also more nearly vertical, so that on looking down the windpipe towards the bifurcation, the right bronchus appears to be a more direct continuation of the trachea than the left. This is, however, by no means constantly the case. Further, it differs from the

left in giving off on its outer side, about 15 mm. to 25 mm. from its origin, a branch which passes to the upper lobe of the right lung. As this branch comes off *above* the place where the right pulmonary artery crosses the bronchus, it is called *eparterial*; the continuation of the bronchus below this branch being called *hyparterial*. On the left side, there is no eparterial branch, and the bronchus passes downwards and outwards for about 5 cm. before giving off any branches.

The *right bronchus* is embraced above by the vena azygos, which hooks forwards over it to end in the vena cava superior. The right vagus descends behind it. At the root of the lung, the eparterial branch is above the pulmonary artery, the hyparterial part is crossed close to its origin by the pulmonary artery, and, lower down, the superior pulmonary vein gets in front of it. The *left bronchus* inclines downwards and outwards, beneath the arch of the aorta, to reach the root of the left lung, where the left pulmonary artery lies first in front of and then above it. It crosses over the front of the œsophagus and the descending aorta. Close to the hilum of the lung, the upper left pulmonary vein is in front of it.

The combined sectional area of the two bronchi is about one-fifth greater than that of the trachea.

The distribution of the branches of the bronchi within the lungs will be described in connexion with those organs.

When the lower part of the cavity of the trachea is viewed from above, the two bronchi are seen to be separated posteriorly by a prominent sagittal ridge (*carina tracheæ*), which broadens anteriorly into a flat triangular area (see fig. 163). Heller and Schrotter[1] found the carina, in 57 per cent. of the cases they investigated, to the left of the median plane; in 42 per cent., in the median plane; and in the remaining 3 per cent., to the right of the median plane.

STRUCTURE OF THE TRACHEA AND MAIN BRONCHI.

Trachea.—The trachea consists of an elastic framework of incomplete cartilaginous rings or hoops united by fibrous tissue, and at one part by plain muscular tissue. It is lined throughout by a mucous membrane, and provided with glands.

The **cartilages** are from sixteen to twenty in number. Each forms a curve of rather more than two-thirds of a circle, resembling the letter C (fig. 162). The depth from above downwards is three or four millimetres, and the thickness 1 mm. The outer surface of each is flat, but the inner is convex from above downwards, so giving greater thickness in the middle than at the upper and lower edges. The cartilages are held together by strong fibrous tissue, which is elastic and yielding to a certain extent, and not only occupies the intervals between them, but is prolonged over their outer and inner surfaces, so that they are, as it were, embedded in the tissue.

The cartilages terminate abruptly behind by rounded ends, but the fibrous tissue is continued across between them, and completes the tube behind: it is here looser in its texture.

The first or highest cartilage, which is connected by the fibrous membrane with the cricoid cartilage of the larynx, is broader than the rest, and often divided at one end. Sometimes it coalesces to a greater or less extent with the cricoid or with the one below. The lowest cartilage, placed at the bifurcation of the trachea, is peculiar in shape; its lower border being prolonged downwards, and at the same time bent backwards, so as to form a curved projection between the two bronchi. The cartilage next above this is slightly widened in the middle line. Sometimes, the extremities of two adjacent cartilages are united, and not

[1] 'Die Carina Tracheæ,' *Zeit. f. kiln. Med.*, Bd. xxxii., 1893.

infrequently a cartilage is divided at one end into two short branches, the opposite end of that next to it being likewise bifurcated so as to maintain the parellelism of the entire series. The use of these cartilaginous hoops is to keep the windpipe open—a condition essential for the free passage of air into the lungs.

Within the fibrous membrane, at the posterior flattened part of the trachea, is a continuous pale reddish layer of *unstriped muscular fibres*, which pass across not only between the ends of the cartilages, but also opposite the intervals; they

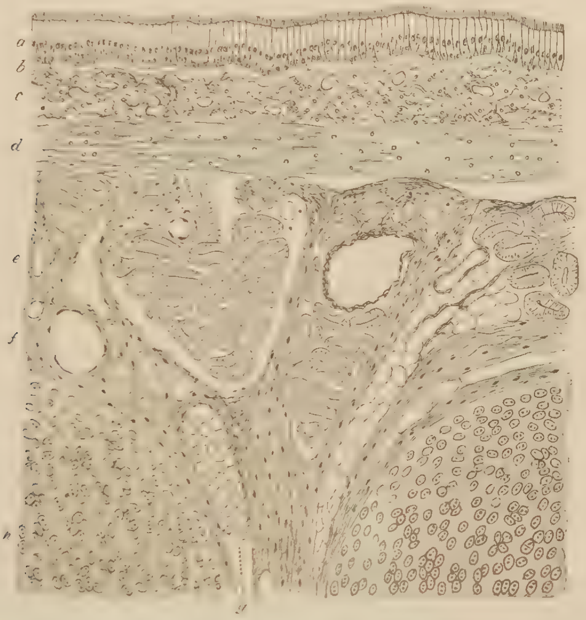


FIG. 164.—LONGITUDINAL SECTION OF THE HUMAN TRACHEA, INCLUDING PORTIONS OF TWO CARTILAGINOUS RINGS. Moderately magnified. (Klein and Noble Smith.)

a, ciliated epithelium; *b*, basement membrane; *c*, superficial part of the mucous membrane, containing the sections of numerous capillary blood-vessels and much lymphoid tissue; *d*, deeper part of the mucous membrane, consisting mainly of elastic fibres; *e*, submucous areolar tissue, containing the larger blood-vessels, small mucous glands (their ducts and alveoli are seen in section), fat, &c.; *f*, fibrous tissue investing and uniting the cartilages; *g*, a small mass of adipose tissue in the fibrous layer; *h*, cartilage.

doubtless serve to narrow the tube by approximating the ends of the cartilages. Those opposite the hoops are attached to the extremities of the latter, and encroach also for a short distance upon their inner surface. Outside the transverse fibres are a few fasciculi, having a longitudinal direction.

The submucous coat consists of loose areolar tissue, which serves to connect the mucous membrane with the fibrous layer and the cartilaginous rings. It contains mucous glands, and a quantity of adipose tissue is often found in it.

The **mucous membrane** is smooth and of a pale pinkish-white colour in health; although when congested or inflamed, it becomes intensely purple or crimson. It contains a considerable amount of lymphoid tissue and is lined by ciliated columnar epithelium.

The trachea is provided with numerous small *mucous glands*. The largest are situated at the back part of the tube, either close upon the outer surface of the fibrous layer or occupying little recesses formed between its meshes. Smaller glands are found between the cartilaginous rings, upon and within the fibrous

membrane, and still smaller ones close beneath the mucous membrane. They are racemose glands, and their cavities are lined with a columnar epithelium: the excretory ducts pass through the muscular layer and the mucous membrane, on the surface of which their orifices are perceptible.

Vessels and nerves.—The **arteries** of the trachea are principally derived from the *inferior thyroid*. The larger branches run for some distance longitudinally, and then join a superficial capillary plexus with polyhedral meshes. The **veins** enter the adjacent plexuses of the *thyroid veins*. A rich plexus of **lymphatics** may readily be injected in the mucous membrane and submucous tissue, but the lymphoid follicles, so common in the alimentary mucous membrane, and also in the walls of the smaller bronchi, are rarely present. When found, they generally surround the ducts of the glands as they pass through the mucous membrane. Numerous lymphatic glands lie in front and at the sides of the trachea (pre-tracheal and para-tracheal), while a group of glands is found between the two bronchi and in front of the œsophagus and aorta.

The **nerves** come from the trunks and inferior laryngeal branches of the vagi, and from the *sympathetic* system. There are said to be numerous ganglia upon them, especially outside the muscular layer at the back of the tube.

In the dog, cat, sheep, and rabbit, the upper half of the trachea is said to be supplied chiefly by the *superior laryngeal* nerve, through the anastomosis between the superior and inferior nerves in the larynx (Kandarazi).

Bronchi.—The general structure of the undivided portions of the bronchi corresponds to that of the trachea in every particular. Their cartilaginous rings, which resemble those of the trachea in being imperfect behind, are, however, shorter and narrower. The number of these rings on the right side varies from six to eight, whilst on the left the number is from nine to twelve.

The bronchi are supplied by the bronchial arteries and veins, and the nerves are from the same source as those of the lower part of the trachea.

Peculiarities according to age.—In the fetus the trachea is flattened before and behind, its anterior surface being even somewhat depressed; the ends of the cartilages touch; and the sides of the tube, which now contains only mucus, are applied to one another. The effect of respiration is at first to render the trachea open, but it still remains somewhat flattened in front, and only later on becomes convex. In consequence of the high position of the larynx in the infant, the cervical part of the trachea is relatively longer at this period of life than in the adult; but this increase in length is somewhat diminished by a higher position of the manubrium sterni. The point of bifurcation of the trachea is generally about a vertebra higher at birth than in the adult. In an infant six months old, the trachea will admit a tube 4 mm. in diameter; at two years, one of 5 mm.; and at six years, one of 6 mm. or 7 mm. Ossification of its cartilaginous rings usually commences in the male at about forty years of age, and in the female at about sixty years (Chievitz).

MEDIASTINUM THORACIS.

The greater part of the thorax is occupied by the lungs, each of which is invested by a serous membrane—the *pleura*. The right and left pleural cavities are separated by a median partition called the *mediastinum* (septum mediastinale). This consists of a layer of pleura on each side, with the heart, great vessels, pericardium, and other structures interposed. The interval between the right and left pleuræ, which is occupied by the structures referred to, is known as the *mediastinal space*. The whole mediastinum is subdivided into the following parts: the *middle mediastinum*—which is coextensive with the pericardium; the *anterior mediastinum*—the part in front of the pericardium; the *posterior mediastinum*—the part behind the pericardium; and the *superior mediastinum*—which is situated above these three subdivisions and extends upwards as far as the root of the neck.

The **superior mediastinum** may be considered to be bounded below by a plane passing from the lower border of the body of the fourth thoracic vertebra behind to the junction of the manubrium with the body of the sternum in front. Its upper limit corresponds to the superior aperture of the thorax. In front are the manubrium and the lower ends of the sterno-hyoid and sterno-thyroid muscles; and behind are the upper four thoracic vertebræ and the lower ends of the longus colli muscles.

It contains the trachea, œsophagus, and thoracic duct; the whole of the arch of the aorta, the innominate artery, and the thoracic parts of the left common carotid

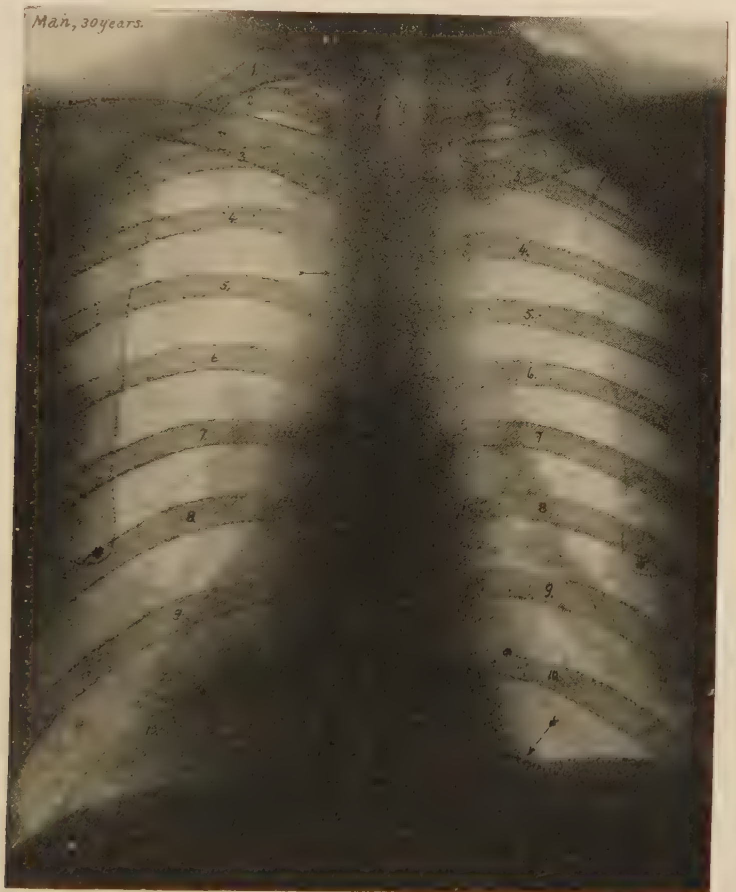


FIG. 165.—A SKIAGRAM OF THE THORAX OF AN ADULT MALE, TAKEN DURING A MODERATELY DEEP INSPIRATION. One-third natural size. (J. S. Dickey.)

The tube was approximately above the mid-point of the sternum, and was 25 inches from the plate. The dark central area, increasing in breadth from above downwards, corresponds to the mediastinum. The horizontal arrow indicates the upper part of the aortic shadow. The cardio-hepatic angle (90°) is indicated by an oblique arrow on the right side between the right auricle and liver shadows.

and subclavian arteries; the innominate veins and upper part of the superior vena cava; the phrenic and vagi nerves, the left inferior laryngeal, and the cardiac nerves; and the cardiac lymphatic glands and remains of the thymus gland.

The **anterior mediastinum** is narrow in its upper half, the two pleuræ coming nearly or quite into contact behind the second piece of the sternum. Below, it is a little broader, the left pleura receding from its fellow, and is bounded

in front by the sternum, sometimes also by the fifth and sixth, and a small portion of the seventh, left costal cartilages, and by the triangularis sterni muscle; behind it, is the pericardium. The enclosed space contains only some areolar tissue, and in its lower part two or three small lymphatic glands (anterior mediastinal glands).

The **middle mediastinum** is the enlarged central portion of the partition, containing, in addition to the pericardium with its contents—namely, the heart, the ascending arota, the trunk of the pulmonary artery, and the lower half of the superior vena cava—the phrenic nerves and accompanying vessels, the arch of the azygos vein, and the roots of the lungs with the bronchial lymphatic glands.

The **posterior mediastinum** is the part between the pericardium, the diaphragm, and the roots of the lungs in front, and the spine behind (from the lower

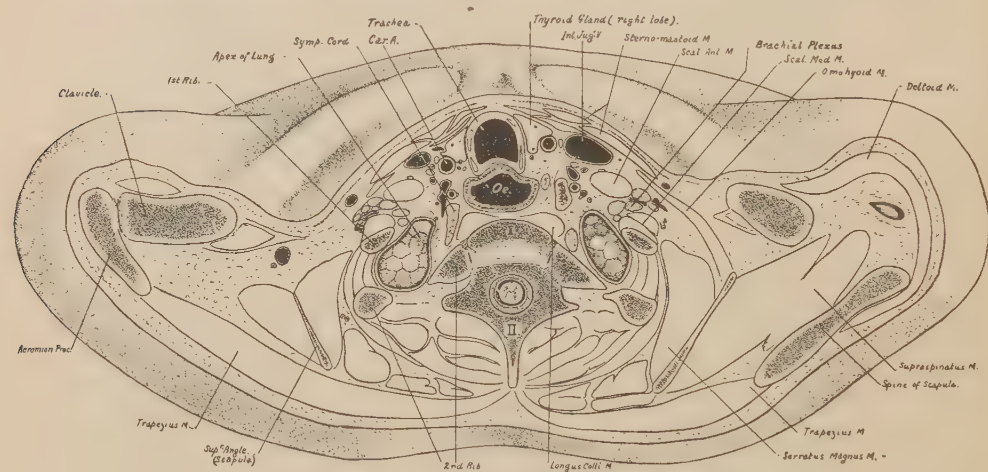


Fig. 166.—Horizontal section of the root of the neck. One-third natural size. (J. S. Dickey.)

The section is about 2·5 cm. above the sternal end of the clavicles and passes through the first and second thoracic vertebræ, the first and second ribs, and the highest part of the lungs. The level of this section, as seen from the right and left lateral aspects of the thorax, is shown in figs. 178 and 179.

border of the fourth thoracic vertebra downwards). It contains between its pleural layers the descending aorta and its right intercostal branches, the œsophagus with the vagi nerves, the azygos veins, the thoracic duct, and the posterior mediastinal lymphatic glands.

THE LUNGS AND PLEURÆ.

The *lungs* occupy by far the larger part of the cavity of the chest, and in health are always in accurate contact with the internal surface of its wall. Each lung is attached at a comparatively small part of its flattened inner or median surface by structures forming the *root.* In other directions the lung is free, and its surface is closely covered by a serous membrane, which is reflected at the root to the corresponding side of the thorax, and named the (right or left) *pleura.*

THE PLEURÆ.

The **pleuræ** are two serous sacs quite distinct from each other. Each consists of a *visceral* and a *parietal* portion, between which is the pleural cavity, containing a very small quantity of fluid, merely sufficient to lubricate the opposing surfaces. The visceral portion (*pleura pulmonalis*) covers the lung and extends into the fissures

between its lobes; the parietal portion lines the ribs and intercostal spaces (*pleura costalis*), covers the upper convex surface of the diaphragm (*pleura*

FIG. 167.—HORIZONTAL SECTION OF THORAX OF A MAN, AGED FIFTY-SEVEN YEARS, AT THE LEVEL OF THE UPPER PART OF THE SUPERIOR MEDIASTINUM, SEEN FROM ABOVE. One-half natural size. (J. Symington.)

3 D.V., body of third thoracic vertebra; M.S., manubrium sterni; *cl*, clavicle; *sc*, scapula; *hu*, humerus; 1, 2, 3, 4, corresponding ribs; R.L., L.L., right and left lungs; T, trachea; *œs*, œsophagus; T.D., thoracic duct; I, innominate artery; R.S., right subclavian artery; L.S., left subclavian artery, in front of this, not lettered, left common carotid artery; I.M., internal mammary artery; AX.A., axillary artery; R.I., L.I., right and left innominate veins; R.A.V., L.A.V., right and left axillary veins; R.V., L.V., right and left vagi nerves; R.P., right phrenic nerve, the left phrenic nerve is on outer side of left common carotid artery; L.R., left inferior laryngeal nerve; R.R.L., right inferior laryngeal nerve; B.P., brachial plexus.

diaphragmatica), enters into the formation of the mediastinum (*pleura mediastinalis*), and extends upwards into the neck (*pleura cervicalis* or *cupula pleuræ*).

At the root of each lung, the visceral and parietal portions of the corresponding pleura are continuous with one another; and at the lower border of the root is a fold of the serous membrane, the two layers of which are continuous above with those in front of and behind the root of the lung. It extends vertically along the

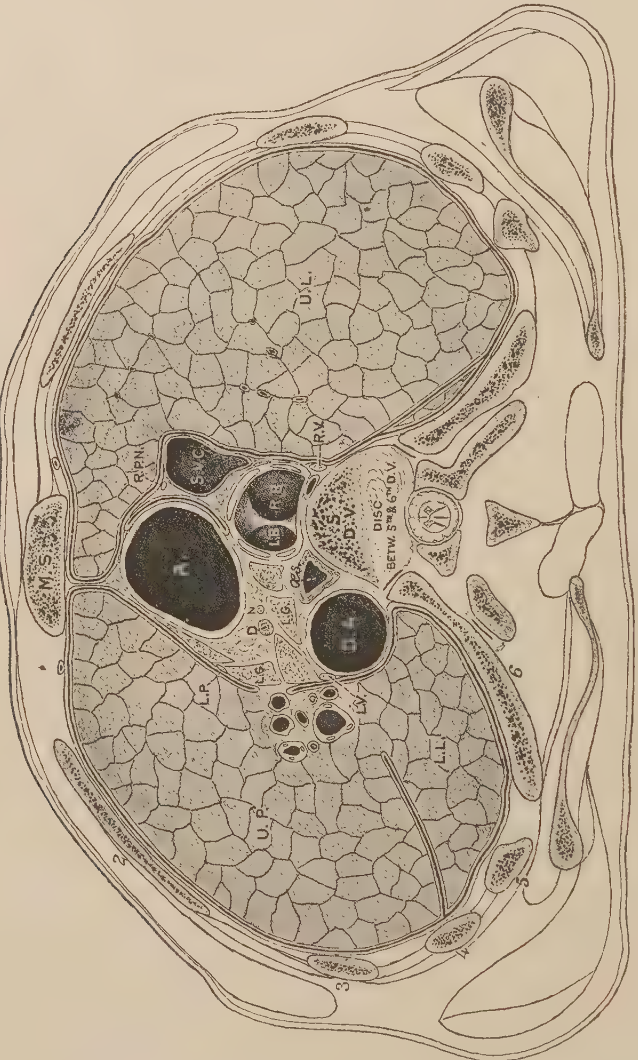


FIG. 168.—HORIZONTAL SECTION OF THORAX OF A MAN, AGED FIFTY-SEVEN YEARS, IMMEDIATELY ABOVE THE BIFURCATION OF THE TRACHEA, SEEN FROM ABOVE. One-half natural size. (J. Symington.)

U.L., upper lobe of right lung; U.P., L.L., upper and lower lobes of left lung; R.B., L.B., origin of right and left bronchi—in this specimen the termination of the trachea was lower than usual; A, arch of aorta; D.A. descending aorta; D, obliterated ductus arteriosus; N, left inferior laryngeal nerve; L.G. lymphatic glands; other letters as in fig. 167.

inner surface of the lung down to the diaphragm, to which it is attached by its extremity; this fold is named *ligamentum pulmonale.*

Along the mediastinal aspect of each pleura, there descends a ligamentous band—an offshoot of the pre-vertebral fascia—attached above to the bodies of the cervical and first thoracic vertebræ, and below to the pericardium and central tendon of the diaphragm. These bands, the 'suspensory ligaments of the diaphragm' of Teutleben, embrace the roots of the lungs, and, in a measure, serve to fix both these and the other parts to which they are attached below.

Relations.—The costal portion of the pleura lines the inner surface of the ribs and intercostal spaces, and posteriorly passes over the heads of the ribs and

the gangliated cord of the sympathetic on to the sides of the bodies of the thoracic vertebræ, where it becomes continuous with the posterior part of the mediastinal pleura, while in front it is reflected backwards to join the anterior part of the mediastinal pleura. This anterior line of reflexion varies at different levels,

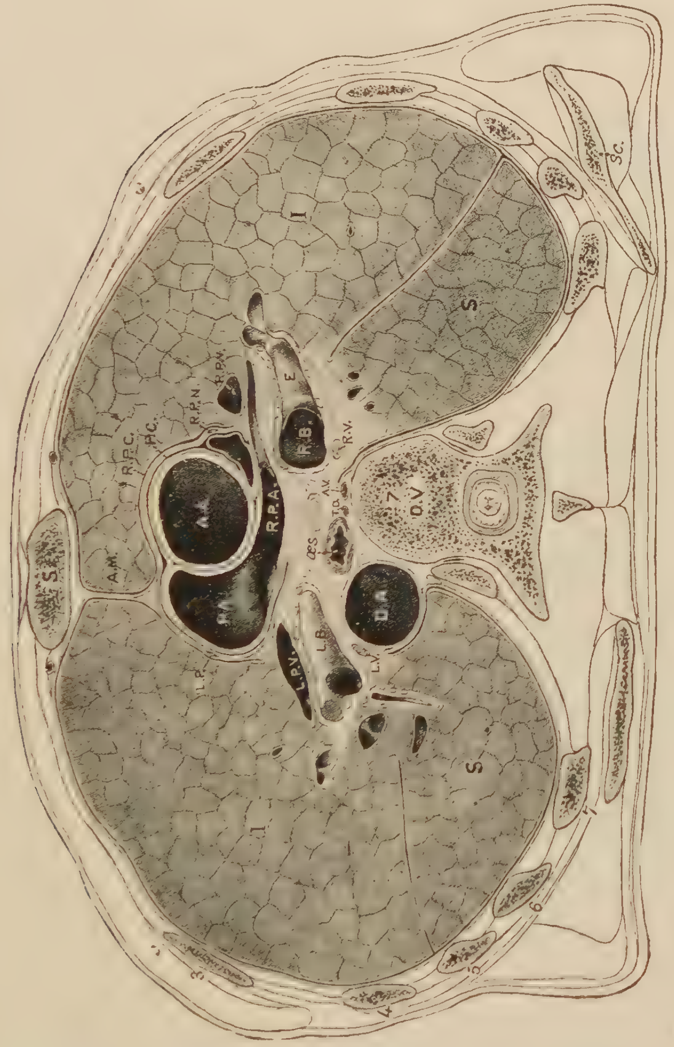


FIG. 169.—HORIZONTAL SECTION OF THE THORAX OF A MAN AGED FIFTY-SEVEN YEARS, AT THE LEVEL OF THE ROOTS OF THE LUNGS, SEEN FROM ABOVE. One-half natural size. (J. Symington.)

I., S., inferior and superior lobes of lungs; E, eparterial bronchus; A.M., anterior mediastinum; R.P.C., right pleural cavity; P.C., pericardial cavity; A.A., ascending aorta; P.A., pulmonary artery; R.P.A., its right branch; R.P.V., L.P.V., right and left pulmonary veins; A.V., azygos vein; S, body of sternum; 7 D.V. body of seventh thoracic vertebra; other letters as in fig. 167.

and also slightly on the two sides (fig. 177). Opposite the manubrium sterni, it may be represented by a line passing from the sterno-clavicular articulation, downwards and inwards, to meet the pleura of the opposite side at the upper edge of the body of the sternum. From this point, the two pleuræ are in close contact down to the level of the upper border of the fifth costal cartilage, where they tend to separate from one another. On the right side, the line of reflexion continues nearly straight, down to the lower end of the body of the sternum, where it begins to turn outwards. On the left side, according to Luschka,[1] it normally diverges from the median line

[1] 'Die Anatomie des Menschen,' *Die Brust.* (1863), s. 268.

at the upper border of the fifth costal cartilage, so that at the level of the sternal end of the fifth costal cartilage it is 1·5 cm., at the sixth 2 cm., and at the seventh 3·5 cm. external to the left border of the sternum. Not infrequently, however, the lateral deviation of the left pleura, opposite the lower end of the sternum, is not

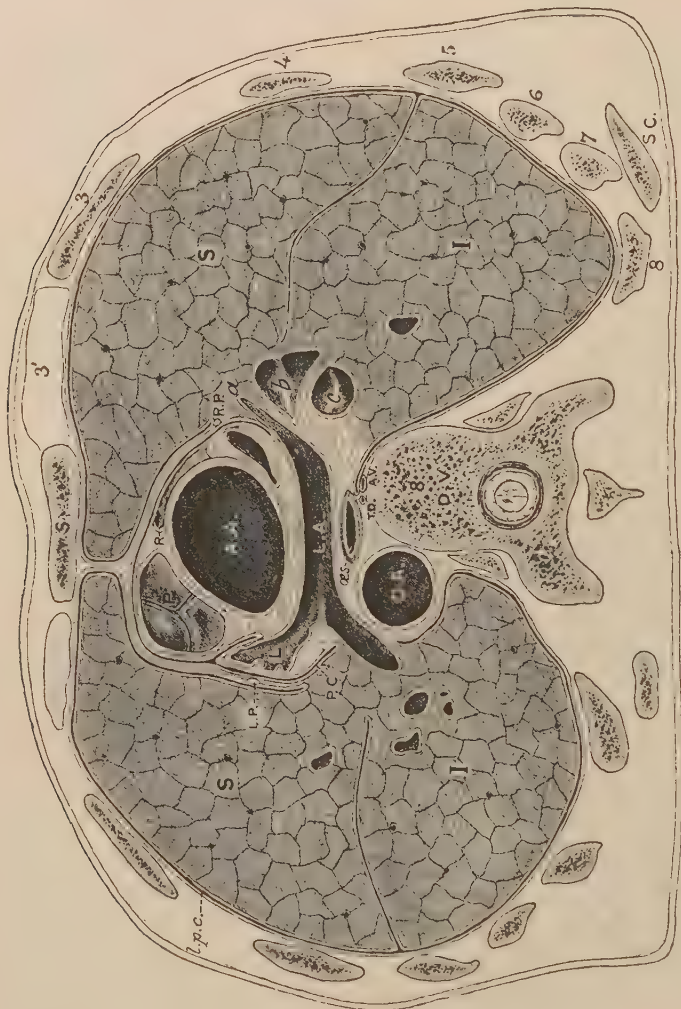


FIG. 170.—HORIZONTAL SECTION OF THORAX OF A MAN, AGED FIFTY-SEVEN YEARS, IMMEDIATELY ABOVE THE PULMONARY VALVES, AND THE RIGHT AURICULAR APPENDIX, SEEN FROM ABOVE. One-half natural size. (J. Symington.)

3′, third costal cartilage; S., I., superior and inferior lobes of lungs; P, on right anterior pulmonary valve; R, tip of right auricular appendix; L, left auricular appendix; L.A., left auricle; *a*, *b*, *c*, branches of right pulmonary artery and vein and of right bronchus *l.p.c.*, left pleural cavity; other letters as in fig. 167.

so marked as described by Luschka. Thus Sick,[1] in seventeen out of twenty-three adults, found that the reflexion of the pleura at the level of the sternal end of the fifth costal cartilage was either behind the sternum or at its left edge. This was also the case in ten out of the twenty-three at the sixth cartilage, and in nine of them at the seventh costal cartilage. Brooks's[2] observations also support this view. In four out of seven cases in which the pleura was quite healthy, he found the reflexion was entirely behind the sternum, while in one it was at the left edge of this bone. He also states that in all the cases the two pleuræ were close to one

[1] Sick, 'Untersuch. über den Verlauf der Pleurablätter am Sternum,' u.s.w., *Arch. f. Anat. u. Physiol.*, Anat. Abt., 1885.

[2] Brooks, St. John, 'On the Relations of the Pleura to the Sternum and Costal Cartilages,' *Trans. of the Roy. Acad. of Med. in Ireland*, vol. vii., 1889.

another as far down as the ensiform cartilage, so that the area of pericardium uncovered by the pleura was reduced to a minimum.

The lower border of the costal pleura is reflected on to the diaphragm opposite a line passing from the lower end of the sternum, outwards, behind the seventh costal

FIG. 171.—HORIZONTAL SECTION OF THE THORAX OF A MAN, AGED FIFTY-SEVEN YEARS, AT THE LEVEL OF THE NIPPLES, SEEN FROM ABOVE. One-half natural size. (J. Symington.)

n, nipple; M, middle lobe of right lung; R.A., right auricle; R.V., right ventricle; L.A., left auricle; L.V., left ventricle; R.P.V., right posterior valve of aortic orifice; *r.p.c.*, right pleural cavity; other letters as in fig. 167.

cartilage nearly as far as its rib; here it leaves the seventh cartilage, and, continuing to pass obliquely downwards and backwards, crosses the eighth, ninth, tenth, and eleventh ribs, and reaches the twelfth rib near its vertebral end. If the twelfth rib be very short, the whole of its anterior surface may be covered, and the pleura pass as low as the transverse process of the first lumbar vertebra (Pansch). When the rib is well developed, it is seldom in contact with the pleura external to its inner half. On the lateral wall of the chest, the pleura will generally be found rather lower on the left than on the right side. Luschka estimates that in the mid-axillary line the pleura reaches to the lower border of the ninth rib on the right side, and to the lower border of the tenth on the left. The inferior limit of the pleura does

not extend to the attachment of the diaphragm, but leaves a portion of the circumference of this muscle in contact with the costal parietes. Owing to the height of the diaphragm on the right side (corresponding to the greater convexity of the liver), the right pleural sac is shorter than the left; it is at the same time wider, as the pericardium does not pass so far to the right as to the left of the median plane.

The upper part of the pleura, moulded upon the apex of the corresponding lung, rises dome-like into the root of the neck, forming the *pleura cervicalis*. It reaches from 3 cm. to 5 cm. above the anterior end of the first rib, and about 1 cm. to 3 cm. above the clavicle, but not higher than the neck of the first rib. Anteriorly, the termination of the internal jugular and subclavian veins, and the commencement of the innominate vein, the internal mammary artery, and the phrenic and vagus nerves lie against it. Behind these structures, and arching outwards over the pleura just in front of its highest point, is the subclavian artery; while, still farther back, the lower trunk of the brachial plexus rests upon it, and the sympathetic cord descends behind it. On the right side, the inferior laryngeal nerve hooks round the subclavian artery, and so gets between this artery and the pleura; while on the left side, the nerve ascends internal to it. The thoracic duct is situated on the inner side of the left pleura as it leaves the thorax. Several lymphatic glands lie in close relation to it.

The cervical pleura is strengthened and supported by several muscles and ligaments. The tendons of insertion of the anterior and middle scalene muscles give small slips to it, and the scalenus minimus terminates below in a dome-like tendinous expansion, often called Sibson's fascia, which covers the pleura and is attached to the inner border of the first rib. Several bands, known as the suspensory, costo-pleural, and vertebro-pleural ligaments, connect it with adjacent structures (see J. S. Dickey, *Applied Anatomy of the Lungs and Pleural Membranes*, 1911, p. 36).

The mediastinal portions of the two pleural sacs constitute, as already described, the lateral boundaries of the mediastinal space. The layers forming the sides of the anterior mediastinum pass backwards from the sternum to the pericardium in close relation with one another, except below, where a triangular interval is sometimes found between them. At the front of the pericardium, the two layers separate, each passing round its own side of the pericardium to the front of the root of the corresponding lung, where it is reflected on to the lung. The part of the mediastinal pleura covering the pericardium is often called *pleura pericardiaca*, and the remaining portions of the mediastinal pleuræ the *laminæ mediastinales*. The phrenic nerve courses to the diaphragm between the pleura and the pericardium. The pleura, which goes from the side of the vertebral column to the back of the root of the lung, bounds the posterior mediastinum. On the right side, it lies in relation with the vena azygos, the right vagus, and the œsophagus; on the left side, with the descending aorta, and low down, with the œsophagus. The two pleuræ are here united by an inter-pleural ligament passing behind the œsophagus and in front of the aorta. At the level of the superior mediastinum, the mediastinal pleura passes backwards from the anterior to the posterior chest wall without being reflected over the lungs. On the right side, it covers the right innominate vein and superior vena cava, the innominate artery, and the right phrenic and vagus nerves, and the trachea; and on the left, the œsophagus and thoracic duct, the left common carotid and subclavian arteries, and the corresponding phrenic and vagus nerves.

In certain situations the surface of the parietal pleura, directed towards the pleural cavity, is not in contact with the visceral pleura, two portions of parietal pleura being in apposition. The part of the pleural cavity, bounded in this way

by the parietal pleura, is called the sinus pleuræ. This space varies in its extent according to the condition of the lungs, being diminished in inspiration and increased during expiration; but in all probability it cannot be completely obliterated, even by forcible inspiration. It is found on both sides, between the chest wall and the diaphragm (*sinus phrenico-costalis*), and on the left side between the chest wall and the pericardium (*sinus costo-mediastinalis*), opposite the lower part of the body of the sternum. It is best marked posteriorly, as here the costal and diaphragmatic portions of the pleura are in contact from about the tenth to the twelfth rib.

Structure.—The pleura possesses the usual characters of serous membranes. The costal part is the thickest, and may be easily raised from the ribs and intercostal spaces, with which it is connected by the *fascia endo-thoracica*. On the pericardium and diaphragm, the pleura is thinner and more firmly adherent; but it is thinnest and least easily detached upon the surface of the lungs.

A difference is also noticeable in the character of the superficial epithelial layers, for, while on the *pleura costalis* these consist of the ordinary flattened cells, on the *pleura pulmonalis* the cells are less distinctly flattened and more granular and polyhedral, but they become flattened out when the lung is distended (Klein). Beneath the serous covering, there is placed a thin layer of *subserous* areolar tissue, mixed with a large number of elastic fibres. It is continuous with the areolar tissue in the interior of the lung, and has been described as a distinct coat under the name of the second or deeper layer of the pleura. In the lungs of many animals—such as the lion, seal, and leopard—this subserous layer forms a very strong membrane, composed principally of elastic tissue; in others—as the guinea-pig—is found a network of plain muscular fibres, which have a general radiating direction from the apex (Klein).

Blood-vessels, lymphatics, and nerves.—The **arterial supply** of the visceral pleura is derived from both the pulmonary and bronchial arteries, and that of the parietal pleura from the intercostal, phrenic, internal mammary, mediastinal, and bronchial arteries. The **veins** correspond. The capillaries beneath the visceral pleura form a coarser network than those of the pulmonary alveoli. **Lymphatic vessels** are abundant in and beneath the pleura, as in other serous membranes, and they communicate in many parts, by means of stomata, with the pleural cavity. In the pleura costalis, the stomata are only found over the intercostal spaces, not over the ribs (Dybkowsky). The lymphatics of the visceral pleura pass with those from the lungs to the bronchial glands. Vessels from the costal pleura pass to small intercostal glands situated near the heads of the ribs, and to the glands along the course of the internal mammary artery. The costal pleural vessels are connected indirectly, through their union with the lymphatics of the fourth and fifth intercostal spaces, with the axillary glands; and there is a connexion between the lymphatic systems of the chest and abdomen, owing to the free anastomosis between the lymph-vessels on the pleural and peritoneal surfaces of the diaphragm. The **nerves** of the visceral pleura are derived from the pulmonary plexuses, and those of the parietal pleura from the intercostal, vagus, phrenic, and sympathetic nerves.

PULMONES.

The shape, surfaces, borders, and relations of the lungs.—Each lung (pulmo) is irregularly conical (fig. 176), and presents for examination a base, an apex, a costo-vertebral and a mediastinal surface—all of which, except the apex, are bounded by definite borders. The base (*basis pulmonis*) looks

downwards, is large, forming about one-sixth to one-eighth of the total superficies of the lung, and has a concave surface, which is moulded on the convex upper surface of the diaphragm. It is partly bounded by a somewhat horseshoe-shaped border, which is thin, projects towards the phrenico-costal sinus of the pleural cavity, and separates the basal from the costo-vertebral surface. The smaller remaining part is irregularly concave, is situated medially, and marks the junction of the base with the mediastinal surface. The greater part of the border uniting the basal and the mediastinal surface fits into the angle at the junction of the pericardium and the diaphragm. On the right side, this angle is known as the cardio-hepatic (fig. 165). Behind this, on the right side, there is a well-marked groove for the inferior vena cava, and on the left side a less distinct one for the œsophagus and aorta. The base of the right lung is separated from the liver by the diaphragm, and that of the left lung by the same muscle from the stomach, the spleen, and sometimes the left lobe of the liver, and the splenic flexure of the colon.

The apex (*apex pulmonis*) is blunt, and reaches into the root of the neck only slightly above the oblique plane of the superior aperture of the thorax, but about 3 cm. or 4 cm. above the first costal cartilage. It is separated by the pleura from a number of important blood-vessels and nerves, as already explained in the account of the pleura.

The apical portion of the lung may be considered, for clinical purposes, as reaching down to a horizontal plane corresponding to the second costal cartilage and junction of manubrium, with body of sternum in front, and the disk between the fourth and fifth thoracic vertebræ behind (J. S. Dickey).

The costo-vertebral surface is convex, and lies in relation to the sternum, upper ten ribs, costal cartilages, and thoracic vertebræ. It may be subdivided into a sterno-costal part, extending as far back as the angles of the ribs, and a vertebro-costal portion, looking backwards and inwards, and resting against the ribs from the angles to their heads, and against the side of the bodies of the vertebræ. The costo-vertebral surface is bounded in front by a well-defined border (except near the apex), separating it from the mediastinal surface : below, by a sharp edge from the basal surface, and behind by a more or less distinct vertical ridge from the mediastinal surface. The part of the lung lying in the concavity formed by the posterior portion of the ribs is often termed the posterior border.

The mediastinal surface (*facies mediastinalis*) presents a vertical fissure or hilum, through which various structures pass into or out of the lung and form its root. Below and in front of the hilum, there is a large concave area for the lodgment of the heart and pericardium : that on the left lung being deeper and more extensive. Above the hilum, the right lung is in close relation with and may show depressions for the right innominate vein, the superior vena cava, the vena azygos, the trachea and œsophagus, and the phrenic and vagus nerves. On the left lung, there is a well-marked groove which arches backwards above the hilum, and then descends behind it. This groove lodges the aorta, and above it are depressions for the left innominate vein and the left subclavian and common carotid arteries. Behind the subclavian groove is an area, opposite which the œsophagus and thoracic duct lie.

At the summits and posterior borders, the extent of the lungs corresponds to that of the pleural sacs which contain them ; but in front and below, the relation is variable, inasmuch as the anterior margins below the level of the third or fourth costal cartilages pass forwards between the mediastinal and costal pleuræ during inspiration, and retire to a variable degree from between them in expiration ; and in like manner the inferior margins descend, during inspiration,

between the costal and diaphragmatic pleuræ: probably, at no time do they ever descend completely to the line of reflexion between those membranes.

The lower edge of the right lung usually extends to the sixth rib in the

Fig. 172.—Sagittal section of the trunk of a man aged forty years, made about 6 cm. to the right of the median plane and viewed from the median aspect. (One-third natural size. (J. S. Dickey.)

mammillary line, to the eighth in the mid-axillary, and to the tenth in the post-scapular line. The left lung is often nearly a rib lower than the right.

Fissures and lobes of the lungs.—The left lung is divided into two lobes by a long and deep fissure, which can be traced on the surface of the lung from the upper and posterior part of the hilum, upwards and backwards, on the inner surface,

and reaches the posterior border at about the level of the fourth rib ; the fissure then passes obliquely downwards and forwards over the outer surface to the lower border, which it joins near its anterior end. This part of the fissure is somewhat

FIG. 173.—SAGITTAL SECTION OF THE TRUNK OF A MAN AGED FORTY YEARS, MADE IN THE LINE OF THE RIGHT NIPPLE, PASSED ABOUT 10 CM. TO RIGHT OF THE MEDIAN PLANE, VIEWED FROM THE MEDIAN ASPECT. One-third natural size. (J. S. Dickey.)

more oblique than the adjacent ribs ; thus, beginning at the fourth rib, it gradually leaves it to gain the inner surface of the fifth rib, which it finally crosses to reach the sixth costal cartilage, a little below the apex of the heart. From the lower border of the lung, the fissure can be seen to pass up the inner surface to the lower part of the hilum. The fissure extends from the surface deeply into the lung,

reaching close to the hilum, and practically dividing the lung into two distinct parts. The upper lobe is the smaller. It forms the apex, the whole of the anterior border, and the greater part of the concavity for the heart. To the

Fig. 174.—Sagittal section of the trunk of a man aged forty years, made about 6 cm. to the left of the median plane, viewed from the median aspect. One-third natural size. (J. S. Dickey.)

lower and larger lobe belong the greater part of the thick posterior border and almost the whole of the diaphragmatic surface, except a small area in front. The highest part of the lower lobe is found at the posterior border of the lung, where it usually reaches to the fourth rib.

In the right lung there are two fissures, dividing it into three lobes, called upper,

middle, and lower. One of these fissures closely corresponds in its position and direction to the one on the left side, except that it is rather more vertical, and joins the lower border of the lung farther outwards. It may be regarded as the

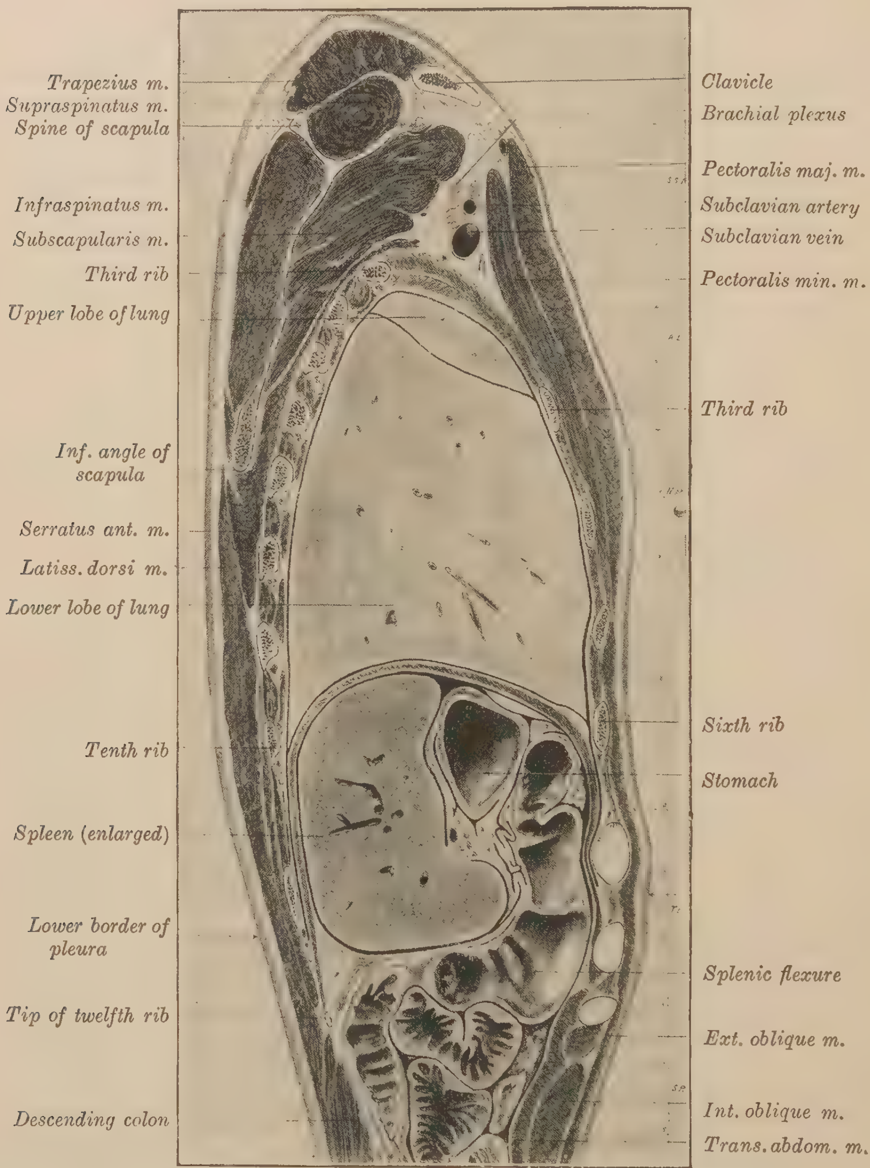


FIG. 175.—SAGITTAL SECTION OF THE TRUNK OF A MAN AGED FORTY YEARS, MADE ABOUT 10 CM. TO THE LEFT OF THE MEDIAN PLANE, VIEWED FROM THE MEDIAN ASPECT. One-third natural size. (J. S. Dickey.)

main fissure, and separates the lower lobe from both the upper and middle lobes. The additional fissure is seen on the outer surface to pass from the main fissure nearly horizontally inwards, and to join the anterior border at the level of the fourth costal cartilage. From this border it can be traced on the inner surface backwards

to the hilum. Like the main fissure, it extends deeply into the lung, and it almost completely cuts off the middle from the upper lobe.

Varieties.—Irregularities in the number and position of the lobes of the lung are not very uncommon. Absence of a lobe, owing to its non-development, is very rare; but cases of its partial union with the adjacent parts of the lung, owing to defective formation of the fissures, are often seen. Accessory lobes often result from fissuring of the primary ones. An accessory lobe on the right side, situated below the root of the lung, and apparently corresponding to the *lobus impar* of various mammals, has been frequently observed. Several cases have also been recorded of an accessory lobe above the root of the lung, which was constricted at its base by the vena azygos.

Differences between the two lungs.—The right lung is shorter than the left, owing to the diaphragm rising higher on the right side to accommodate the

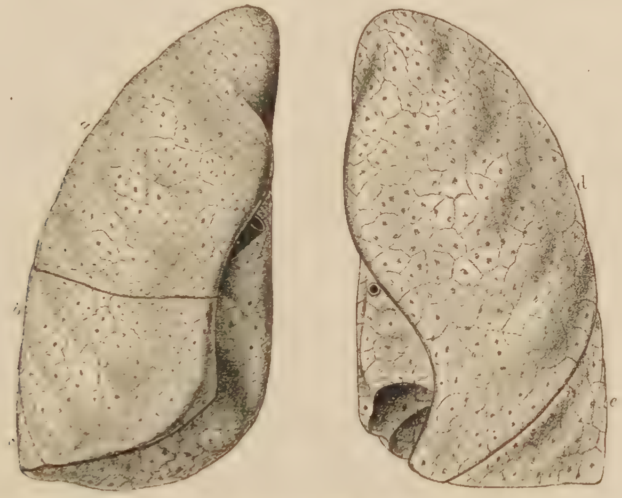


FIG. 176.—VIEW OF THE LUNGS FROM BEFORE, DRAWN FROM THE MODELS OF HIS.

a, b, c, upper, middle, and lower lobes of the right lung; *d, e*, upper and lower lobes of the left lung.

liver; whilst the left lung is the narrower, owing to the heart and pericardium encroaching on the left half of the thorax. On the whole, however, as is seen on a comparison of their weights, the right is the larger of the two lungs.

As already described, the right lung has an additional fissure and lobe, as compared with the left lung, and the mediastinal surfaces also differ, mainly, owing to a want of bilateral symmetry of the heart and great vessels which lie between the two. The anterior border of the right lung passes almost straight down, behind the sternum, from the level of the second to the sixth costal cartilage; whereas the corresponding border of the left lung turns outwards and downwards, opposite the fourth costal cartilage, and then usually curves inwards before joining the lower border of the lung. This notch in the anterior border of the left lung is known as the *incisura cardiaca*, and the process below it is called the lingula.

In consequence of this notch, an area of the heart on the left side of the median plane is uncovered by lung. The part of this area to the left of the sternum is often called the area of præcordial dullness, or the area of superficial cardiac dullness. The area of the heart uncovered by lung is irregularly triangular in shape, the three fixed points being: (*a*) one at midsternum, opposite the fourth costal cartilages; (*b*) another at the apex beat; (*c*) a third at midsternum, at the junction of the body of the sternum with the ensiform cartilage. The line joining the first two of these points is irregularly curved, with the convexity directed

upwards and outwards. The line joining the second with the third point is slightly curved, with the convexity directed downwards and to the right. At the inner part of its lower border, cardiac dullness frequently merges in hepatic dullness.

Roots of the lungs.—The root of each lung is composed of the bronchus or subdivision of the air-tube, and the large blood-vessels, together with nerves, lymphatic vessels, and glands, connected together by areolar tissue, and enclosed by the reflexion of the pleura.

The roots of the lungs are situated at the level of the bodies of the fifth, sixth, and seventh, and often also the eighth, thoracic vertebræ. The root of the right lung lies behind the superior vena cava and part of the right auricle, and below the azygos vein, which arches over it to enter the superior cava. That of the left lung passes below the arch of the aorta, and in front of the descending aorta. The phrenic nerve descends in front of the root of each lung, and the vagus nerve behind; whilst the ligamentum pulmonis is continued from the lower border. The bronchi, together with the bronchial arteries and veins, the lymphatics and lymphatic glands, are placed on a plane posterior to the great blood-vessels, whilst the pulmonary veins are in front of the arteries. The pulmonary plexuses of nerves lie on the anterior and posterior aspects of the root, beneath the pleura; the posterior plexus being the larger of the two.

On the right side, the undivided portion of the bronchus is usually altogether above the right pulmonary artery; on the left side, the undivided portion of the bronchus, which is considerably longer than on the right side, extends to below the level of the left pulmonary artery, which crosses it. On both sides, the pulmonary veins are below the corresponding arteries.

Distribution of the bronchi within the lungs.—As already mentioned, the right bronchus gives off a branch near its origin, which is distributed in the upper lobe of the lung (fig. 180, *ep*), while the left bronchus passes into the hilum of the lung before it begins to divide. Each bronchus possesses a main stem, which goes downwards, backwards, and outwards, through the lung, to end near the posterior part of the base, and from this stem a series of ventral and dorsal branches are given off, so that the general distribution of the bronchi may be described as bipennate. In addition to these two rows of dorsal and ventral branches, accessory ones are occasionally met with, coming off from the main trunk in its passage through the lower lobe. These usually arise from the front, and are intermediate in position between the dorsal and ventral series. The ventral branches are usually large and more regular than the dorsal. The lower part of the bronchial stem is not easily demonstrated in man, owing to its small size as compared with the branches arising from it.

The origin and distribution of the branches of the two bronchi differ in several respects from one another, and the two sets are summarised as follows by Dr. J. Stuart Dickey (*Applied Anatomy of the Lungs and Pleural Membranes*, 1911).

'The right bronchus gives off the following branches :—

1. Apical or eparterial bronchus arises 2 cm. from the trachea, turns upwards and outwards, and divides into an anterior, a posterior, and an ascending branch, which supplies the upper lobe alone.

The main trunk continues to run downwards and outwards, and gives off four or five ventral, three or four dorsal, branches, and one subcardiac branch.

2. The first ventral bronchus: supplies the middle lobe alone.

3. (*a*) The remaining three or four ventral branches supply the bulk of the lower lobe, except its apex and its posterior or vertebral surface, which are supplied by—

(*b*) The dorsal branches, small in size, running backwards and inwards;

(*c*) The subcardiac branch: runs to the lower part of the mediastinal surface and to the inner part of the base. This portion of the lung may form a distinct lobe.

The left bronchus is somewhat different from the right.

1. A very large branch, arising about 4 cm. or 5 cm. from the trachea, divides into two branches, which are believed to represent the apical and first ventral bronchi of the right side; by means of these two branches the upper lobe is supplied.

(*a*) The *apical* branch gives off an anterior, a posterior, and an ascending branch, as on the right side.

(*b*) The first ventral supplies the lower part of the upper lobe, including the lingula.

2. The second to the fifth ventral; and the three or four dorsal bronchi springing from the continuation of the left bronchial stem supply the lower lobe much as on the right side.'

Our present knowledge of the distribution of the bronchi is mainly due to the investigations of Aeby,[1] Ewart,[2] and Narath.[3]

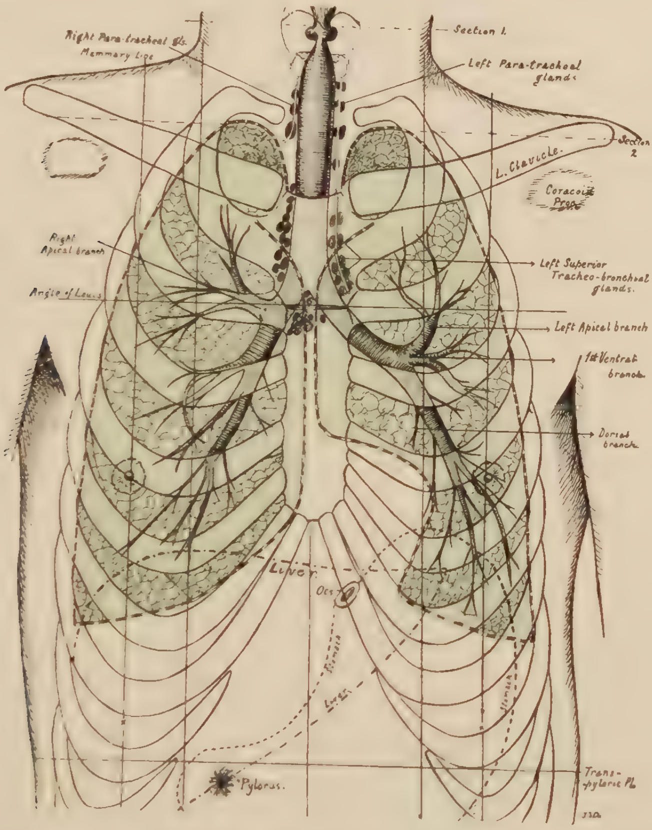


FIG. 177.—POSITION OF THE LUNGS (BLUE), VIEWED FROM THE FRONT, IN A MAN AGED THIRTY-EIGHT YEARS. One-fourth natural size. (J. S. Dickey.)

The cavities of the larynx, trachea, and main bronchi are given as found in this specimen; but the position of the smaller bronchi are based upon a metallic cast by Merkel.

Aeby opposed the old idea that the division of the bronchi was dichotomous, and asserted that the bronchus of each lung possessed a main stem, which traversed the organ in a somewhat curved direction, and terminated at the posterior part of its base. This main stem gave off a series of ventral and dorsal branches, and occasionally also accessory bronchi. He further divided the main branches of the bronchi into eparterial and hyparterial—these names expressing the relations of the bronchi to the right and left pulmonary arteries. From the examination of various mammals, he concluded that the eparterial bronchi might be absent, unilateral, or paired. As it is present in man on the right side only and supplies the upper lobe, while the hyparterial bronchi go to the middle and lower lobes of the right lung and the upper and lower

[1] *Der Bronchialbaum der Säugetiere und des Menschen*, 1880.
[2] *The Bronchi and Pulmonary Blood-vessels*, 1888.
[3] *Der Bronchialbaum der Säugetiere und des Menschen*, 1901.

lobes of the left lung, Aeby held that the upper lobe of the right lung was not represented in the left lung.

Ewart's work consists of a very thorough and elaborate examination of the distribution of the bronchi in the human subject, and he endeavours to show that the scheme of distribution proposed by Aeby is not applicable to man. He does not believe that the relation of the pulmonary

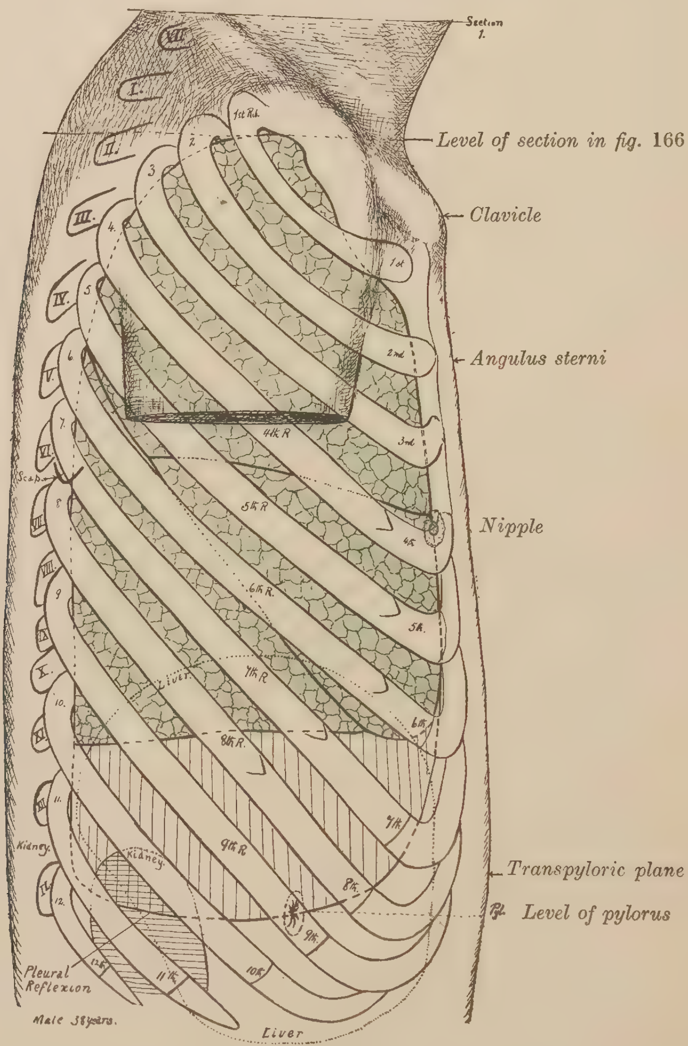


FIG. 178.—RIGHT LATERAL ASPECT OF THE THORAX OF A MAN AGED THIRTY-EIGHT YEARS, SHOWING THE POSITION OF THE LUNG (BLUE). One-third natural size. (J. S. Dickey.)

The vertically striped area below the lung indicates the extent of the costo-phrenic pleural sinus.

arteries to the main branches of the bronchi is a competent standard for the determination of the morphological value of the bronchial tubes. He shows the difficulty of tracing the lower part of Aeby's main bronchial stem, and supports the dichotomous division of the bronchi as being more consistent with the facts than Aeby's view of a main stem with dorsal and ventral branches. Ewart proposes a very elaborate classification of the bronchi, for particulars of which the reader must be referred to his monograph.

Some idea of the extensive character of Narath's investigations may be formed from the fact that his book contains 242 figures in the text and seven large plates. The work is largely comparative and embryological. He supports the view of Aeby that each lung is traversed

by a stem-bronchus with ventral and dorsal branches; but admits that while this stem is very evident in the lower mammals, especially in the Echidna, its lower part is obscured in the primates by changes in the form of the thorax, by which the lung becomes shortened and at the same time increased in its transverse and dorso-ventral diameter. He holds that an apical bronchus

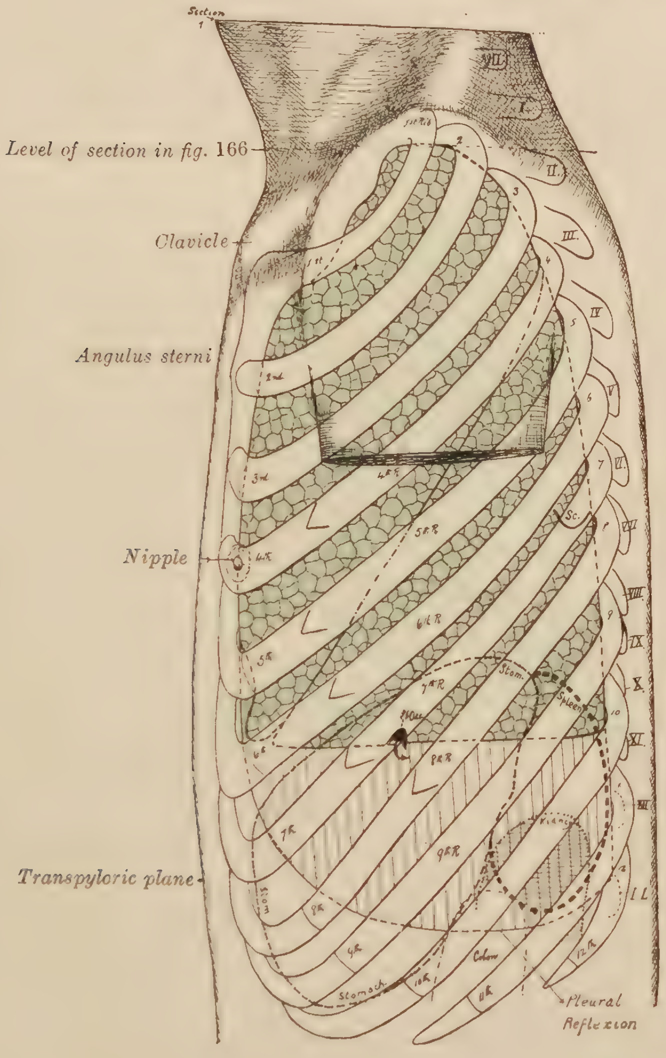


FIG. 179.—LEFT LATERAL ASPECT OF THE THORAX OF A MAN AGED THIRTY-EIGHT YEARS, SHOWING THE POSITION OF THE LUNG (BLUE). One-third natural size. (J. S. Dickey.)

The vertical striped area below the lung indicates the extent of the costo-phrenic pleural sinus.

(eparterial of Aeby) exists on both sides, although its origin differs in different mammals. In man, the upper lobe is supplied by a trunk, which divides into an apical and the first ventral branch; while on the right side, the apical supplies the upper lobe, and the first ventral the middle lobe. The upper lobe of the left lung is, therefore, homologous with the upper and middle lobes of the right lung. Narath's work contains a copious bibliography on the subject.

Structure of the bronchial tubes.—Within the lungs, the air-tubes are not flattened behind like the bronchi and trachea, but form completely cylindrical tubes. The cartilages no longer appear as imperfect rings running only upon the

front and lateral surfaces of the air-tube, but are disposed over all sides of the tube in the form of irregularly shaped and incomplete rings of various sizes. These are most developed at the points of division of the bronchi, where they form a sharp concave edge, projecting inwards into the tube. They may be traced—becoming rarer and rarer and more reduced in size—as far as bronchi one millimetre in diameter; at about this point the mucous glands disappear, but the mucous membrane retains its ciliated epithelium. The muscular fibres, which in the trachea and main bronchi are confined to the back part of the tube, surround the smaller bronchi with a continuous layer of annular fibres lying inside the

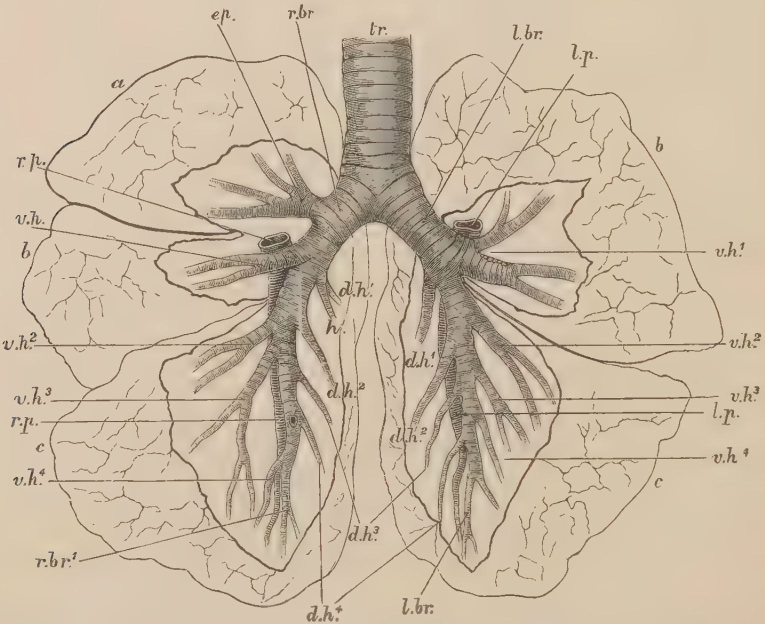


FIG. 180.—SKETCH SHOWING THE LOWER END OF THE TRACHEA, ITS DIVISION INTO THE TWO BRONCHIAL TRUNKS, AND THE COURSE AND CHIEF BRANCHES OF THESE WITHIN THE LUNGS FROM BEFORE. (After Aeby.)

a, upper, *b*, middle, *c*, lower lobe of the right lung; *b′*, upper, *c′*, lower lobe of the left lung; *r.p.*, right pulmonary artery; *l.p.*, left artery; *r.br.*, right bronchial trunk; *l.br.*, left bronchial trunk; *ep.*, on the right side, eparterial branch supplying the upper lobe; $v.h.^1$, first ventral hyparterial bronchus supplying the middle lobe on the right side, the upper lobe on the left; $v.h.^2$, $v.h.^3$, $v.h.^4$., the remaining ventral hyparterial branches distributed in the lower lobe on each side; $d.h.^1$, $d.h.^2$, $d.h.^3$, $d.h.^4$, the four dorsal hyparterial branches distributed on both sides in the posterior and inner part of the lower lobe; *h*, accessory bronchus arising close to the first dorsal hyparterial bronchus on the right side, and representing the one which supplies the azygos lobe in some animals. The main branches of the pulmonary vessels are distributed like the bronchi. Within the lung the arterial trunks run behind the bronchial branches, the venous trunks in front.

cartilaginous plates; they are found, however, beyond the place where the cartilages cease to exist, and appear as irregular annular fasciculi—even in the smallest tubes.

The smallest divisions of the bronchi, about 0·2 mm. in diameter, are known as the terminal or lobular bronchioles; they end in the pulmonary lobules, and each of these lobules may be regarded as a miniature lung. According to W. S. Miller (fig. 185), a lobular bronchiole divides into two or three passages called the vestibules, out of which open dilatations known as the atria, and these are continued into several blind diverticula termed infundibula. The vestibules, atria, and infundibula are beset with recesses, alveoli, or air-cells, lined with

pavement epithelium, and having in their walls a fine capillary network intervening between the branches of the pulmonary artery and the tributaries of the pulmonary vein.

Blood-vessels of the lungs.—The pulmonary arteries and veins are of large size, and at the root fill the interspaces between the large bronchi, so that no room remains here for any pulmonary tissue, and the origin of the lobular bronchioles is relegated to more peripheral zones. The branches of the pulmonary artery form within the lung a duplicate of the bronchial tree, and do not anastomose with one another. Each bronchus is accompanied by a single artery, which tends to be

FIG. 181.—CAST OF THE INTERIOR OF THE TRACHEA AND BRONCHI, WITH THEIR CHIEF RAMIFICATIONS WITHIN THE LUNGS. (Aeby.)

This cast shows a type of division frequently met with, the right bronchus being almost in continuation of the line of the trachea.

a, eparterial branch ; *b*, *c*, hyparterial branches (ventral and dorsal).

associated with the part of the bronchial wall which is cartilaginous, and its minute branches enter the lobules in close association with the terminal bronchioles.

The radicles of the *pulmonary veins* arise from the capillary network of the alveoli and from that of the smaller bronchial tubes. Their radicles are collected in the septa between the infundibula, apart from the terminations of the arteries and bronchioles. The branches of these veins which arise from the infundibula, near the surface of the lung, run alone for a certain distance through the substance of the organ. They finally either join some deeper vein which is passing towards the hilum, or they remain superficial, forming a wide-meshed plexus near the surface of the lung, finally passing towards the hilum to join the larger veins near the root of the lung. The veins from the more deeply lying infundibula form

frequent communications, and finally coalesce into large branches, which ultimately accompany the bronchial tubes and arteries, coursing as a rule in front of the bronchial tubes, and thus proceed to the root of the lung. In their course together through the lung the artery is usually found above and behind a bronchial tube, and the vein below and in front.

The pulmonary vessels differ from the systemic in regard to their contents, inasmuch as the arteries convey venous blood, whilst the veins carry arterial blood.

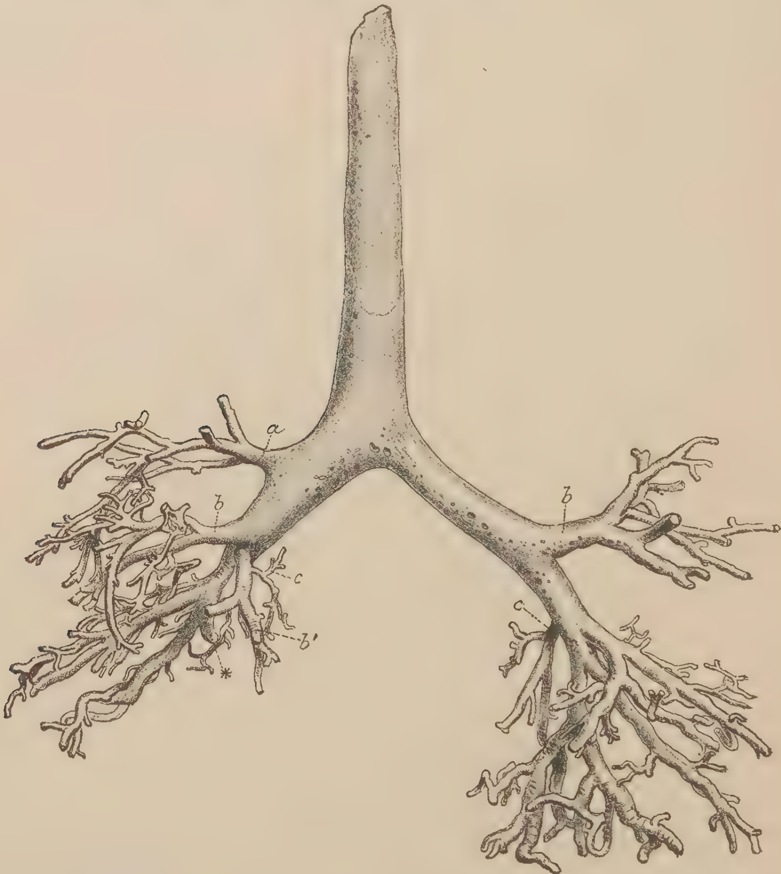


Fig. 182.—Cast of the interior of the trachea and bronchi, with their chief ramifications within the lungs. (Aeby.)

This cast shows a type of division less frequent than the last, the right and left bronchi being almost at right angles to one another.

a, eparterial branch ; *b*, ventral hyparterial branches ; *b′*, accessory (azygos) branch ; *c*, dorsal hyparterial branches.

The pulmonary veins, unlike the other veins of the body, are not more capacious than their corresponding arteries : indeed, according to Winslow, Santorini, Haller, and others, they are somewhat less so. These veins have no valves. The arteries of different secondary lobules are usually independent ; the veins freely anastomose. (For further particulars regarding the distribution of these vessels, consult W. Ewart, 'The Bronchi and Pulmonary Blood-vessels,' London, 1888.)

Bronchial vessels.—The bronchial arteries and veins, which are much smaller than the pulmonary vessels, carry blood for the nutrition of the lung. The *bronchial arteries*, from one to three in number for each lung, arise from the aorta, or from

an intercostal artery, and follow the divisions of the air-tubes through the lung. They are ultimately distributed in three ways : (1) many of their branches ramify in the bronchial lymphatic glands, the coats of the large blood-vessels, and in

FIG. 183.—PORTION OF A TRANSVERSE SECTION OF A BRONCHIAL TUBE, HUMAN (6 MM. IN DIAMETER). Magnified thirty diameters. (F. E. Schultze.)

a, cartilage and fibrous layer with mucous glands, and, in the outer part, a little fat ; in the middle, the duct of a gland opens on the inner surface of the tube ; *b*, annular layer of involuntary muscular fibres ; *c*, elastic layer—the elastic fibres in bundles which are seen cut across ; *d*, columnar ciliated epithelium.

the walls of the bronchial tubes, supplying an outer capillary plexus with transverse meshes to the muscular coat, and an inner plexus with close longitudinal meshes to the mucous membrane, which in the lobular bronchioles is continuous with that supplied by the pulmonary artery ; (2) others form plexuses in the interlobular areolar tissue ; (3) branches pass from the interior to the surface of the lung beneath the pleura, and join the network of pulmonary venous capillaries which is found there.

The *bronchial veins* have not quite so extensive a distribution in the lung as the bronchial arteries, since part of the blood carried by the bronchial arteries is returned by the pulmonary veins. The superficial and deep bronchial veins unite at the root of the lung, opening on the right side into the azygos, and on the left usually into the hemiazygos vein.

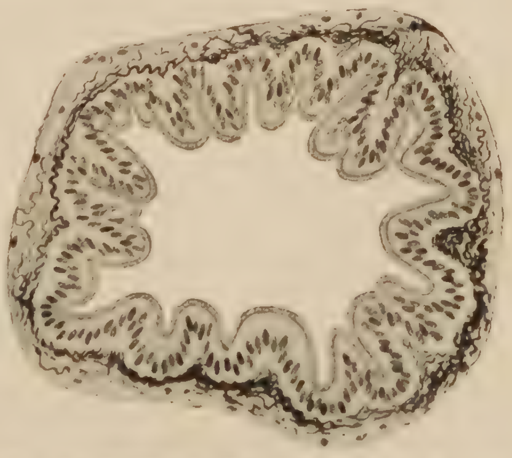


FIG. 184.—SECTION OF A SMALL BRONCHIAL TUBE, HUMAN. Magnified 280 diameters. (Sobotta.)

According to Zuckerkandl ('Ueber die Anastomosen der Venæ pulm. mit den Bronchialvenen,' u.s.w., *Sitzungsber. d. Wiener Akad.*, Bd. lxxxiv., 1881), it is not only at the extremities of the bronchial tubes that the blood brought by the bronchial arteries is returned by the pulmonary veins, but in other parts small bronchial veins open into pulmonary branches ; and even veins which receive branches from the larger bronchi, from the bronchial glands, and from the posterior surface of the pericardium, empty their contents partly into the great trunks of the pulmonary veins.

A few small branches of the *intercostal arteries* also pass to the pulmonary pleura and surface of the lung through the ligamentum pulmonale (Turner).

Zuckerkandl ('Ueber die Verbindungen zwischen den arteriallen Gefässen der mensch. Lungen,' *Sitzungsber. d. Wiener Akad.*, Bd. lxxxvii., 1883), described an anastomosis in the lung, between the branches of the pulmonary and bronchial arteries; but this is disputed by Miller ('The Arrangement of the Bronchial Blood-vessels,' *Anat. Anzeig.*, Bd. xxviii., 1906), who found that by using a granular injecting mass, which would not pass through capillaries, no anastomosis could be demonstrated.

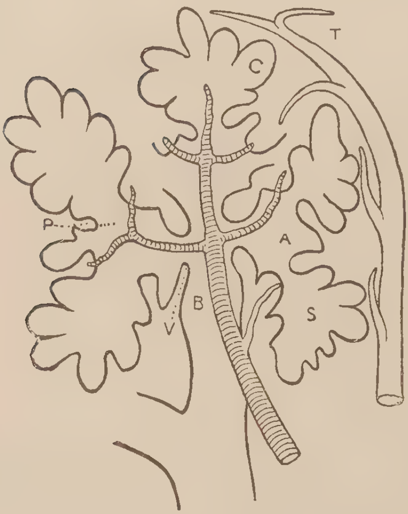


FIG. 185.—DIAGRAM OF THE ENDING OF A BRONCHIAL TUBE. (W. S. Miller.)

B, termination of lobular bronchiole in V, vestibule, by means of which it communicates with the atria, A; S, air-sac, opening out of atrium and beset with air-cells, C; P, lobular arteriole; T, one of the lobular venules.

Lymphatics.—The *alveolar* lymphatics of the lung take origin from lymphatic capillaries in the inter-alveolar septa, and those near the surface of the lung come into connexion with the sub-pleural lymphatic plexus. They join to form vessels which accompany the branches of the pulmonary artery and vein, running on the walls of those vessels in twos or threes, connected by numerous cross branches, and in some cases almost completely surrounding the blood-vessel.

Other lymphatics, which may be distinguished as *bronchial*, originate in plexuses in the mucous membrane of the bronchial tubes. Hence they pass through the muscular coat to form another plexus in the fibrous layer, where they are most numerous on the side opposite the accompanying branch of the pulmonary artery. Here they are not infrequently found to enclose nodules of lymphoid tissue. The branched connective-tissue corpuscles and cell-spaces with which the lymphatics are in connexion at their origin, send processes upwards to the inner surface of the air-tubes and alveoli, between the epithelial cells (like the pseudo-stomata of the serous membranes). Lymphoid tissue is found, according to Arnold, in various parts: namely—under the pulmonary pleura, in the peri-vascular and peri-bronchial tissue in the bronchial wall, and around the alveolar passages.

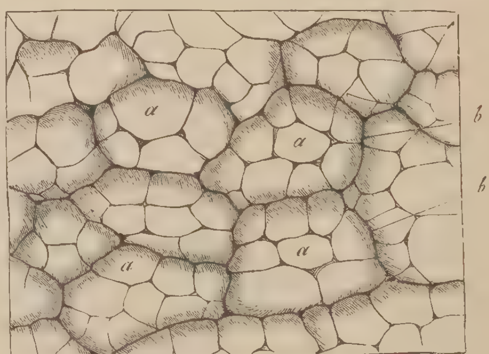


FIG. 186.—PORTION OF THE OUTER SURFACE OF THE COW'S LUNG. Magnified thirty diameters. (From Kölliker, after Harting.)

a, pulmonary alveoli filled artificially with wax; *b*, the margins of the smallest lobules.

The lymphatic vessels of the lungs are connected with numerous lymphatic glands found in the lungs near the hila (broncho-pulmonary), and in relation to

the main bronchi outside the lungs and the thoracic part of the trachea (bifurcatory and tracheo-bronchial).

Nerves.—The nerves of the lung come from the *anterior and posterior pulmonary plexuses*, which are formed chiefly by branches from the vagi nerves, joined by others from the sympathetic system. The fine nerve-cords enter at the root of the lung, and follow the air-tubes. According to Remak—whose account has been confirmed and added to by the more recent observations of Stirling and others—they include both white fibres (derived in all probability from the vagus),

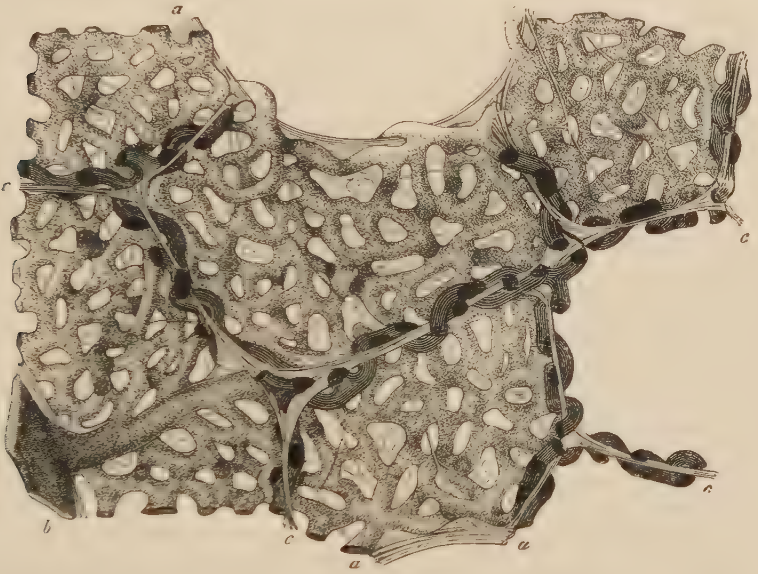


FIG. 187.—SECTION OF INJECTED LUNG, INCLUDING SEVERAL CONTIGUOUS AIR-CELLS OR ALVEOLI. Highly magnified. (F. E. Schultze.)

a, a, free edges of air-cells; *c, c*, partitions between neighbouring air-cells seen in section; *b*, small arterial branch giving off capillaries to the alveoli. The looping of the vessels to either side of the partitions is well exhibited. Between the capillaries is seen the homogeneous alveolar wall with nuclei of connective-tissue corpuscles and elastic fibres.

and grey filaments (proceeding from the sympathetic), and have ganglion-cells, both singly and in groups, upon them in their course. In the lower vertebrates (frog, newt), the nerves are chiefly distributed to a layer of plain muscular tissue, which is everywhere found taking part in the composition of the relatively simple pulmonary wall (Stirling). Berkeley has described the nerve-endings in mammals as forming a plexus of fine fibrils with interspersed stellate cells, such as have been noticed in many glands and mucous membranes. The ultimate ending appears to be in open arborisations upon and between the alveoli.

Weight of the lungs.—The lungs vary much in weight according to the quantity of blood they may happen to contain, as well as from other causes. The weight of both lungs together, as generally stated, ranges from 30 oz. to 48 oz., the more prevalent weights being found between 36 oz. and 42 oz. (1,300 grms. in the male and 1,023 grms. in the female, according to W. Krause). The proportion borne by the right lung to the left is nearly that of 22 oz. to 20 oz., taking the combined weight of the two at 42 oz. (682 grms. to 618 grms., taking the combined weight as 1,300 grms.). The lungs are not only absolutely heavier in the male than in the female, but appear to be heavier in proportion to the weight of the body.

Spitza ('Note on the True Weight of the Human Lungs,' *American Journal of Anatomy*, vol. iii.; *Proc. Assoc. Amer. Anatomists*) examined the lungs of six criminals executed by electricity and found their weight to be much less than usually stated: the average weight of the right lung being 280 grms. and the left 253 grms. This is not quite half that given by Krause. The lightness was due to the almost complete absence of blood in the lungs.

Dimensions of the lungs.—In sections through the thorax of adult males, the average diameters of the lungs are as follows: the greatest vertical, 22 cm. to 25 cm.; the greatest antero-posterior, 13 cm. to 16 cm.; and the greatest transverse, 9 cm. to 11 cm. In such specimens, the size of the lungs is approximately those during life at the end of expiration; but at the completion of the inspiratory act all the diameters would be greater. The collapse of the lungs after removal of the chest wall is so extensive that they only occupy about one-third of the volume which they possess at the end of an inspiration.

Air-capacity of the lungs.—At the end of a deep inspiration in a well-formed, vigorous man, the air contained in the lungs may amount to nearly 5,000 c.c.; while in collapsed lungs, such as are found in the cadaver after opening the pleural cavities, the amount is about 1,500 c.c. The average amount of air inspired or expired in ordinary breathing is about 500 c.c.

Physical properties.—The substance of the lung is of a light, porous, spongy texture, and, when healthy, is buoyant in water; but in the fetus, before respiration has taken place, and also in certain cases of congestion, collapse, or consolidation from disease, the entire lungs, or portions of them, sink in that fluid. The specific gravity of a healthy lung, as found after death, varies from 0·345 to 0·746. When the lung is fully distended its specific gravity is 0·126, whilst that of the pulmonary substance, entirely deprived of air, is 1·056 (Krause). When pressed between the fingers, the lungs impart a crepitant sensation, which is accompanied by a peculiar noise; both effects being caused by the air contained in the tissue. On cutting into the lung, the same crepitation is heard, and there exudes from the cut surface a reddish frothy fluid, which is partly mucus from the air-tubes and air-cells, and partly serum of blood, rendered frothy by the admixed air.

The pulmonary tissue is endowed with great elasticity, in consequence of which the lungs collapse to about one-third of their bulk when the thorax is opened. Owing to this elasticity also, the lungs, if artificially inflated out of the body, contract to their previous volume when the air is again allowed to escape.

In infancy, the lungs are of a pale rose-pink colour, which might be compared to blood-froth; but as life advances, they become darker, and are mottled or variegated with spots, patches, and streaks of dark slate-colour, which sometimes increase to such a degree as to render the surface almost unfiormly black.

The dark colouring-matter found in these streaks is in the form of granules and collections of granules, frequently not enclosed in cells; it is deposited in the interstitial areolar tissue mostly near the surface of the lung, and is not found so abundantly in the deeper substance. It exists sometimes in the air-cells, and on the coats of the larger vessels. Its quantity increases with age, and is said to be less abundant in females than in males. In persons who follow the occupation of miners, more especially colliers, the lungs are often intensely charged with black matter. The black substance seems mainly to consist of particles of carbonaceous substance. It is found also in the bronchial glands; indeed, it appears to be taken up in large measure by the lymphatics. In exceptional cases, the adult lungs exhibit only very slight streaks of pigment.

Condition in the fetus and changes after birth.—In the fetus, the lungs contain no air, and consequently sink in water. They undergo very rapid and remarkable changes after birth, in consequence of the commencement of respiration: these affect their size, position, form, consistence, texture, colour,

and weight, and should be carefully studied, as furnishing the only means of distinguishing between a still-born child and one that has respired.

1. *Position, size, and form.*—In a fetus at the full period, or in a still-born child, the lungs, comparatively small, lie packed at the back of the thorax, and do not entirely cover the sides of the pericardium. When respiration begins, the lungs expand, and completely cover the pleural portions of that sac, and are also in contact with almost the whole exent of the thoracic wall, where it is covered with the pleural membrane. At the same time their previously thin, sharp margins become more obtuse, and their whole form is less compressed.

2. *Consistence, texture, and colour.*—The introduction of air and of an increased quantity of blood into the fetal lungs, which ensues immediately upon birth, converts their tissue from a compact, heavy, granular, yellowish-pink, gland-like substance, into a loose, light, rose-pink, spongy structure, which, as already mentioned, floats in water. The changes thus simultaneously produced in their consistence, colour, and texture, occur first at their anterior borders, and proceed backwards through the lungs: they, moreover, appear in the right lung a little sooner than in the left.

3. *Weight.*—The *absolute weight* of the lungs, having gradually increased from the earliest period of development to birth, undergoes at that time, from the quantity of blood then poured into them, a very marked addition, amounting to more than one-third of their previous weight: for example, the lungs before birth weigh about one ounce and a half, but after complete expansion by respiration, they weigh as much as two and a half ounces. The *relative weight* of the lungs to that of the body, which at the termination of intra-uterine life is about one to seventy, becomes, after respiration, on an average about one to thirty-five or forty—a proportion which is not materially altered through life. The *specific gravity* is at the same time changed from 1·056 to about 0·342.

UROGENITAL SYSTEM.

The urinary and genital organs are grouped together under the term urogenital system (apparatus urogenitalis), as these organs are closely associated with one another in their development, and their excretory ducts unite to form a common urogenital passage or sinus by which they communicate with the exterior.

ORGANA UROPOËTICA.

The urinary organs (*organa uropoëtica*) consist of the *kidneys*, the glands by which the urine is secreted, and the *ureters*, *bladder*, and *urethra*, serving for its reception and evacuation.

RENES.

The **kidneys** (*renes*), two in number, are compound tubular glands, which form the hind kidneys or meta-nephri of the embryologist and comparative anatomist, as they are preceded in ontogeny and phylogeny by two other pairs of excretory organs, known as the pro-nephri and meso-nephri (Wolffian bodies). In the human subject, these organs begin to retrogress at an early period of intra-uterine life, and soon cease to act as excretory organs, their function being taken up by the meta-nephri, which persist throughout life, and are consequently termed the permanent kidneys.

Position.—The kidneys are deeply situated in the loins, lying one on each side of the vertebral column, at the back part of the abdominal cavity and behind the peritoneum. Their long axes are not quite vertical, but incline from above somewhat forwards and outwards. They are on a level with the last thoracic and the upper two or three lumbar vertebræ (fig. 192), the right kidney being usually a little lower than the left—probably in consequence of the vicinity of the large right lobe of the liver. The upper ends of the kidneys are anterior to the twelfth ribs, and their lower extremities several centimetres above the iliac crests. The transpyloric plane corresponds to about the junction of the upper third with the lower two-thirds of the kidneys, and a sagittal section in the lateral plane would divide the kidney through nearly its entire length, but leaving rather the larger half lateral to the section. Each kidney, therefore, lies in adjacent portions of the epigastric, hypochondriac, umbilical, and lumbar regions of its own side.

Variation in the height of the kidney.—The kidney exhibits a considerable range of variation with respect to its height in relation to the vertebral column. F. Helm ('Zur Topographie des menschlichen Nieren,' *Anat. Anzeig.*, Bd. xi., 1895) found that not infrequently it reached nearly as high as the upper border of the eleventh thoracic vertebra, but it was very rarely opposite the tenth. On the other hand, it may be a vertebra or a vertebra and a half lower than normal; only very exceptionally does its lower pole extend downwards to the side of the fifth lumbar vertebra.

Although the kidney does not usually reach as low as the iliac crest it may do so without any signs of disease or enlargement. Thus out of 264 male subjects examined to determine the relation of the lower end of the kidneys to the highest part of the iliac crest (see Thomson, 'Report of the Committee of Collective Investigations,' *Jour. Anat. and Phys.*, vol. xxvi., October, 1891),

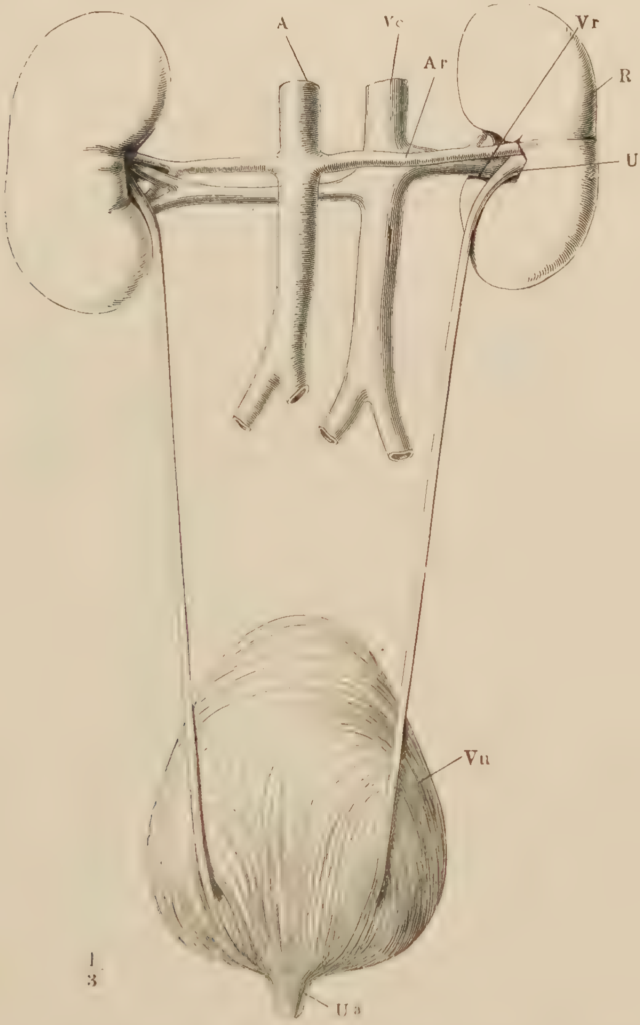


FIG. 188.—THE URINARY ORGANS OF THE FEMALE, FROM BEHIND. (Henle.)

R, right kidney; U, commencement of the ureter; A, aorta, Ar, right renal artery, Vc, inferior vena cava; Vr, right renal vein; Vu, urinary bladder; Ua, commencement of urethra.

twenty-four were at or below the crests, sixteen at the crest, and only six below it. In 184 females, twenty-nine were at or below the crest, and of these eighteen were below the crest. Downward displacement of the kidneys is thus more common in women than men. These observations also showed that the right kidney was on the average lower than the left.

Form and relations.—The surface of the kidney is smooth and of a deep red colour. It is bean-shaped, and possesses two surfaces—an *anterior* looking forwards and outwards, and a *posterior* backwards and inwards; two borders—a lateral, which is convex, and a median, concave; and two somewhat enlarged convex

extremities—*upper* and *lower*. The so-called inner border of the kidney always points more or less forwards, and frequently its hilum looks directly forwards.

The posterior surfaces of the two kidneys lie against the abdominal wall, and are nearly identical in their relations; but the connexions of their anterior or

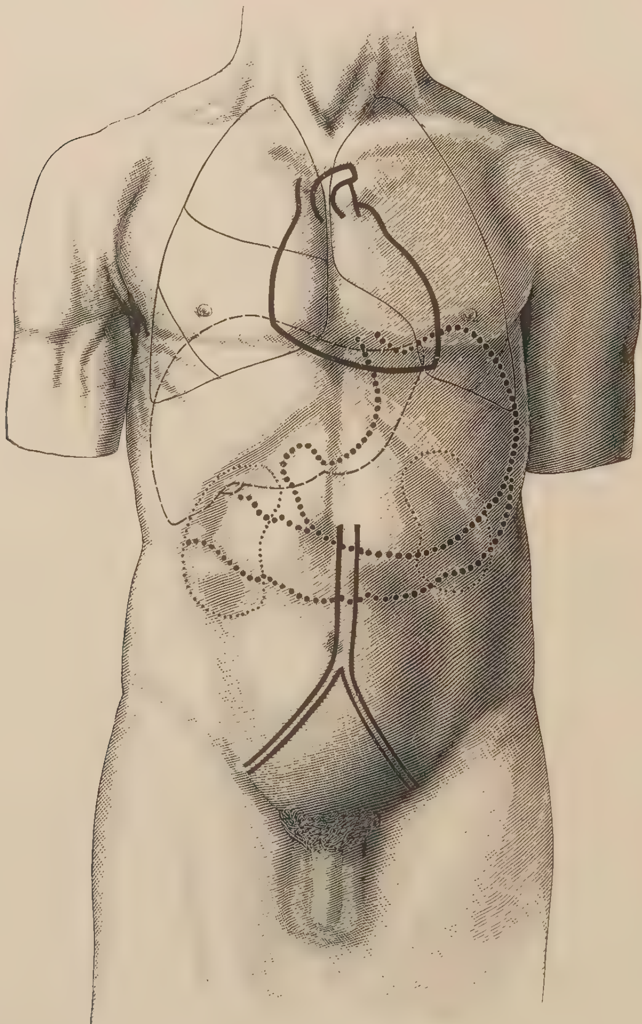


Fig. 189.—Front view of the trunk, showing the relative positions of the principal thoracic and abdominal viscera, etc. One-fifth natural size. (R. J. Godlee and G. D. Thane.)

The outlines of the lungs and their large fissures are indicated by thin lines; the position of the heart and great vessels (superior vena cava, arch of aorta, and pulmonary artery), as well as the abdominal aorta and the common external iliac arteries, by thick lines; the liver is represented by a broken line; the stomach and transverse colon by thick dotted lines; and the kidneys by thin dotted lines.

visceral surfaces differ on the two sides. There is a variable amount of adipose tissue, but no peritoneum behind the kidneys. The upper part of the posterior surface rests upon the diaphragm; this muscle separating the kidney from the pleura, the twelfth rib, and sometimes also from the eleventh rib (see fig. 79). Below the twelfth rib, the psoas and quadratus lumborum muscles are related to

this surface, and the areas for these two muscles are often separated by a distinct border on the kidney (see fig. 193). The last thoracic, the ilio-hypogastric, and the ilio-inguinal nerves pass obliquely outwards and downwards between the kidney and the quadratus lumborum.

The anterior surface of both kidneys usually exhibits a more or less distinct transverse ridge, above and below which, it slopes as an inclined plane towards each extremity,[1] this division of the surface into two parts being usually best marked

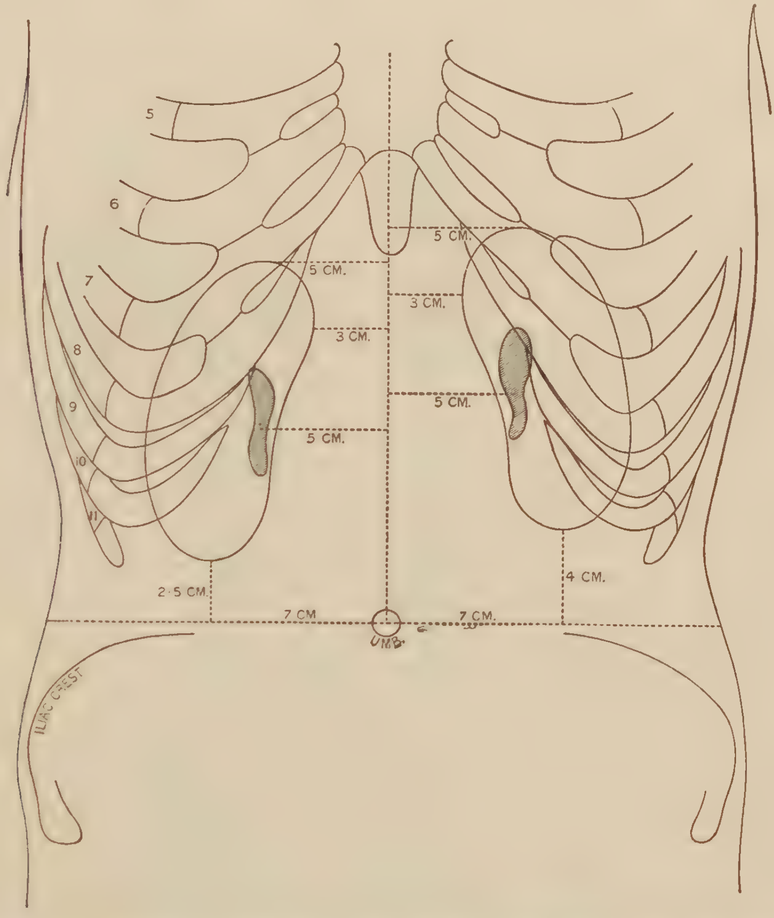


FIG. 190.—DETERMINATION OF THE POSITION OF THE KIDNEYS ON THE FRONT OF THE BODY: SCHEME. (R. J. Godlee and G. D. Thane.)

The position of the hilum is indicated on each kidney by a finely striped area.

on the left kidney. The *anterior surface* of the right kidney is covered on its upper and outer part by peritoneum, which intervenes between it and the large renal impression on the liver. Near its median border the second part of the duodenum descends in contact with it, while more externally it is crossed by the commencement of the transverse colon; both these portions of the intestine are destitute of peritoneum posteriorly. The lower end of the right kidney is again covered by peritoneum. The *anterior surface* of the left kidney is crossed transversely, just

[1] D. J. Cunningham, 'On the Form of the Spleen and the Kidneys,' *Jour. Anat. and Phys.*, vol. xxix., July 1895.

above the level of the hilum, by the pancreas and the splenic vessels. Above this, there is usually a small area covered by the stomach ; the lesser sac of the peritoneum intervening. Below the pancreas, it is separated from some coils of the

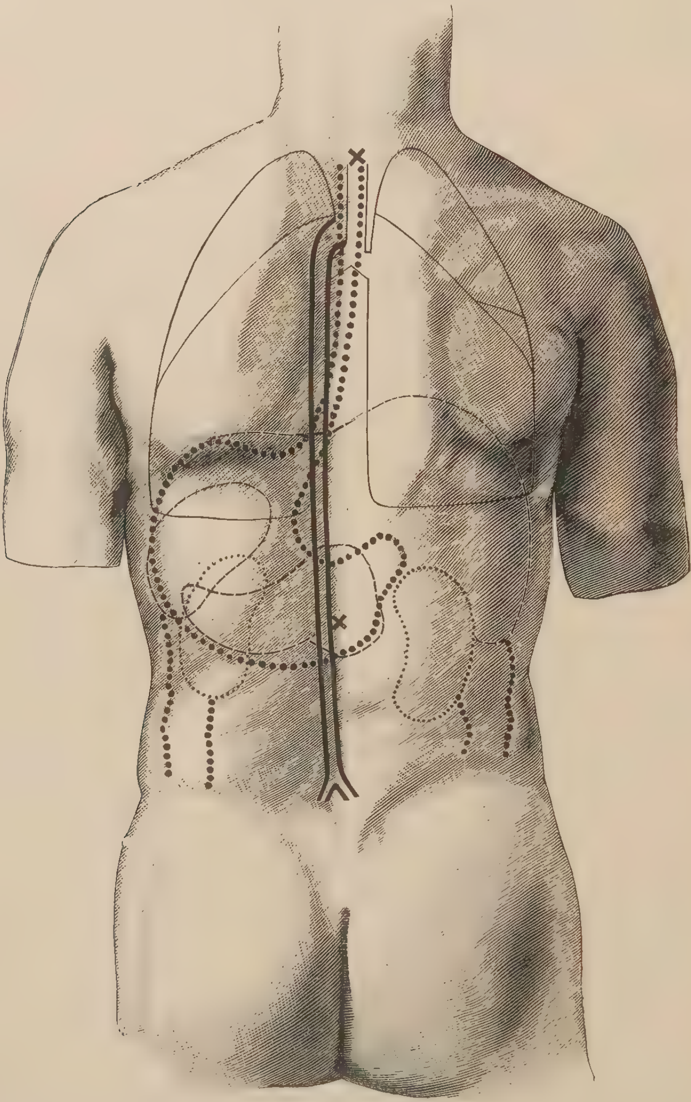


FIG. 191.—POSTERIOR VIEW OF THE TRUNK, SHOWING THE RELATIVE POSITIONS OF THE PRINCIPAL THORACIC AND ABDOMINAL VISCERA, ETC. One-fifth natural size. (R. J. Godlee and G. D. Thane.)

The several objects are indicated in the same manner as in fig. 189 : the trachea and lungs by thin lines, the aorta by thick lines, the liver, pancreas, and spleen by broken lines, the œsophagus, stomach, ascending and descending colon by thick dotted lines, and the kidneys by thin dotted lines ; ×, ×, seventh cervical and first lumbar spines.

small intestine by the peritoneum. The *upper end* of the right kidney is capped by the right suprarenal gland and the liver, and that of the left kidney by the left gland and the spleen. The *lower ends* of the kidneys are generally smaller than the upper. They reach on an average to within about 3 cm. to 5 cm. of the iliac

crest. The *lateral border* of the right kidney is covered in about its upper two-thirds by the liver, and the left kidney in its upper half or more by the spleen. The ascending colon on the right side and the splenic flexure and descending colon on the left are found at the lower and outer parts of the right and left kidneys respectively. The *median border* presents about its middle third a vertical fissure termed the *hilum*, bounded by anterior and posterior lips and serving for the passage of the blood-vessels, lymphatics, nerves, and excretory duct of the kidney. The direction

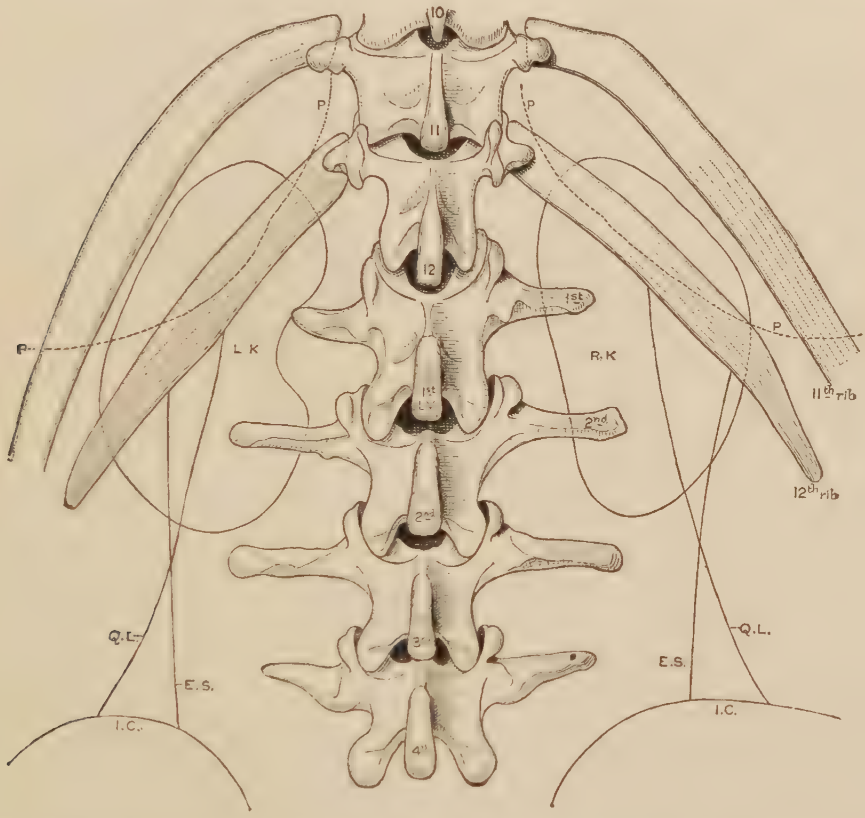


FIG. 192.—OUTLINE VIEW OF THE KIDNEYS FROM BEHIND, CONSTRUCTED FROM A SERIES OF HORIZONTAL SECTIONS THROUGH THE TRUNK OF AN ADULT MALE. One-half natural size. (J. Symington.)

R.K., L.K., right and left kidneys; E.S., outer border of erector spinæ muscle; Q.L., outer border of quadratus lumborum muscle; I.C., iliac crest; P.P., dotted line to show lower limit of costal pleura.

of the hilum varies considerably in different subjects, and even on the two sides in the same individual; but, as a rule, it looks more forwards than towards the middle line, and not infrequently the posterior lip reaches as far forwards as the anterior one.

D. J. Cunningham[1] has shown that the kidneys, when hardened *in situ*, present facets corresponding to the viscera with which they are in contact, and the posterior surfaces also have slight depressions opposite the last rib, and the transverse processes of the upper two lumbar vertebræ.

Variations in position according to age.—The ureter is developed as an outgrowth from the Wolffian duct. This ureter-bud grows at first in a dorsal and then in a cranial direction,

[1] *Op. cit.*, p. 207.

and its expanded cranial end or renal pelvis acquires its definite fetal position, opposite the second lumbar vertebra, in embryos 9·5 mm. to 13 mm. in length. The kidney, which is formed from outgrowths of collecting-tubules from the renal pelvis and from the surrounding meta-nephrogenetic tissue, corresponds in the first half of fetal life to the upper three lumbar vertebræ; while in the

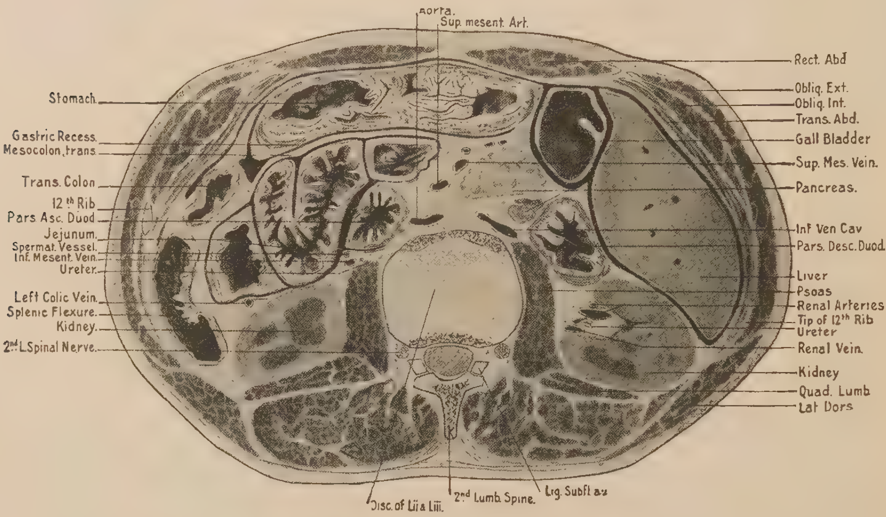


FIG. 193.—HORIZONTAL SECTION OF THE ABDOMEN OF A MAN, AGED FIFTY YEARS, MADE AT THE LEVEL OF THE DISK BETWEEN THE SECOND AND THIRD LUMBAR VERTEBRÆ. (P. T. Crymble.)

The right kidney is divided opposite its hilum; the left, below its hilum.

For other horizontal sections through the kidneys, see figs. 80, 81, and 83; and for sagittal sections, figs. 172, 173, and 174.

second half, the cranial pole rises to the eleventh rib, and the caudal one to the upper border of the fifth lumbar vertebra (W. Felix, in Keibel and Mall's *Manual of Human Embryology*, vol. ii., 1912). During the first year after birth, Alglave ('Note sur la situation du rein chez le jeune

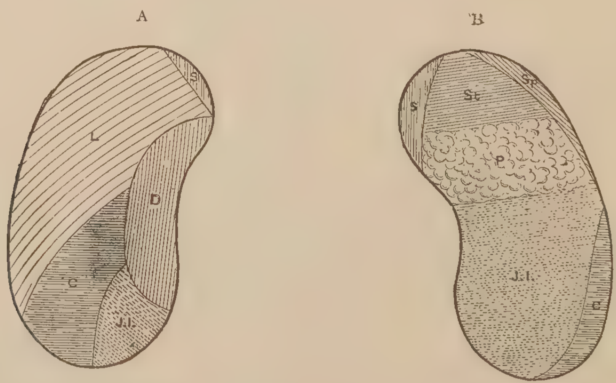


FIG. 194.—DIAGRAM TO ILLUSTRATE THE RELATIONS OF THE KIDNEYS, AS SEEN FROM BEFORE. (J. Symington.)

A, *right kidney*: S, area for right suprarenal gland, non-peritoneal; L, area for liver, peritoneal; D, area for second part of duodenum, non-peritoneal; C, area for ascending colon and hepatic flexure of colon, non-peritoneal; J.I., area for convolutions of jejuno-ileum, peritoneal. B, *left kidney*: S, area for left suprarenal gland, non-peritoneal; St, area for stomach, peritoneal; Sp, area for spleen, peritoneal; C, area for splenic flexure and descending colon, non-peritoneal; J.I., area for convolutions of jejuno-ileum, peritoneal; P, area for pancreas, non-peritoneal.

enfant,' *Bull. et Mém. Soc. Anat.*, vol. lxxxv., Paris, 1910) found the caudal pole of the kidney in the iliac fossa in sixteen out of thirty-two cases examined by him; between the first and second years, this pole was in the iliac fossa in only three out of nine cases, and after the second

year it was always above the iliac crest. This change appears to be due to a more rapid growth of the posterior abdominal wall in the lumbar region as compared with that of the kidney, by which the space between the last rib and the iliac crest is considerably increased.

The kidney undergoes two rotations round its long axis during its growth. The renal pelvis and collecting-tubules are at first dorsal to the ureter, but they soon change so as to occupy a position lateral to the ureter. Subsequently, there is a rotation in the opposite direction—usually of about 45°—so that the hilum looks obliquely forwards and inwards.

Size and weight.—The kidneys measure about 11 cm. to 12 cm. in length, 6 cm. in breadth, and 3 cm. to 4 cm. in thickness. The left is usually longer and narrower and a little heavier than the right. The weight of the kidney is usually stated to be about 120 grms. to 140 grms. in the male, and somewhat less in the female. Vierordt gives 277 grms. as the weight of the two kidneys together in the male. The specific gravity is about 1·050.

Varieties.—The kidneys sometimes vary from their normal form, being either longer and narrower, or shorter and more rounded. The characteristic fetal lobulation may persist in the adult. Occasionally, one kidney is very small, while the other is proportionately enlarged. Numerous cases are recorded of absence of one kidney—most frequently the left. The single kidney is usually enlarged, but not invariably. The occurrence of an additional kidney is rare. A. F. Dixon ('Supernumerary Kidney: the Occurrence of Three Kidneys in an Adult Male Subject,' *Jour. Anat. and Phys.*, vol. xlv., January 1911) has collected records of ten cases, several of which were observed by surgeons during abdominal operations. In Dixon's case, the right kidney was normal, but on the left side there were two kidneys—upper and lower—separated from one another by a distance of 2·8 cm. The ureter from the upper kidney was joined by that from the lower, so that there were only two ureteric openings into the bladder. W. M. Mills has recently described another case in the same *Journal* (vol. xlvi., April 1912). In this specimen also, the additional kidney was on the left side.

Instances are now and then met with in which the two kidneys are joined by their lower ends across the front of the great blood-vessels and vertebral column. The conjunct organ has usually the form of a horseshoe, with the convexity downwards. It is due to a fusion of the caudal ends of the two kidneys.

Sometimes two united kidneys are situated on one or other side of the vertebral column in the lumbar region, or—but much more rarely—in the cavity of the pelvis.

The kidney may be *movable*, owing to the laxity of its areolar and adipose capsule, or, in rare cases, *floating*, when it has a more or less distinct meso-nephron, and the peritoneum moves with the organ. These conditions occur much more frequently in connexion with the right than with the left kidney (see W. Arbuthnot Lane, 'Floating Kidney,' *Jour. Anat. and Phys.*, vol. xx., April 1886).

Structure.—The kidney is surrounded by a proper fibrous coat, **tunica fibrosa**, which forms a thin, smooth, but firm investment, closely covering the organ. It consists of dense areolar tissue, with numerous fine elastic fibres, and can easily be detached from the substance of the gland, to which it adheres by minute processes of connective tissue and vessels. Underneath the fibrous tunic in the human kidney is an incomplete layer of plain muscular fibres.

Outside the tunica fibrosa is a quantity of loose fatty tissue (*capsula adiposa*). The amount of this tissue varies considerably. It is best developed on the posterior surface of the kidney, at the hilum and the lower pole, while on the anterior surface it is often absent. It is continuous above with the adipose tissue round the suprarenal gland. External to the capsula adiposa is a layer of fibrous tissue (*fascia renalis* of Gerota).[1] This fascia is continuous, laterally, with that lining the transversalis muscle, and at the lateral border of the kidney it splits into two layers, one passing in front and the other behind the kidney. The anterior layer is continued forwards in front of the renal vessels, the aorta, and the inferior vena cava, to unite with the layer of the opposite side, while the posterior layer is connected with the fascia on the quadratus lumborum and psoas muscles, and may sometimes be traced to the front of the bodies of the vertebræ. The two layers also

[1] 'Beiträge zur Kenntnis des Befestigungsapparates der Niere,' *Arch. f. Anat.*, 1895.

enclose the supra-renal gland, and, uniting above this organ, blend with the fascia on the under-surface of the diaphragm. Below the kidney, the union of the two layers is not usually distinct, but they are gradually lost in the fascia of the iliac fossa. The kidneys move up and down during respiration, but excessive movement is checked by the surrounding fasciæ, the renal blood-vessels, and the tonicity of the muscular wall of the abdomen.

On splitting open the kidney by a longitudinal section, from its lateral to its median border, the fissure named the hilum (fig. 195, *h*, *h*) is found to extend some distance into the interior of the organ, forming a cavity called the *sinus* of the kidney (*s*). This is enclosed on all sides, except at the hilum, by the solid substance of the organ, and is lined by an inward prolongation of the fibrous coat. The sinus contains the calyces and the upper part of the pelvis of the ureter, branches of the renal blood-vessels, lymphatics, nerves, and fat. The solid part consists of *cortical* and *medullary* substances; the latter being arranged in conical masses named *pyramides renales* [Malpighii], with their broad bases (*b*, *b*) directed towards the surface, and their points towards the sinus, where they form prominent *papillæ renales*. The pyramids are embedded in the cortical substance, which separates them from the surface of the kidney, and to a greater or less extent from each other. The papillæ, from seven to twelve in number, project into the calyces minores of the ureter. Some of these papillæ may correspond to a single pyramid, but as a rule they represent the fusion of the apical portions of two or more adjacent pyramids.

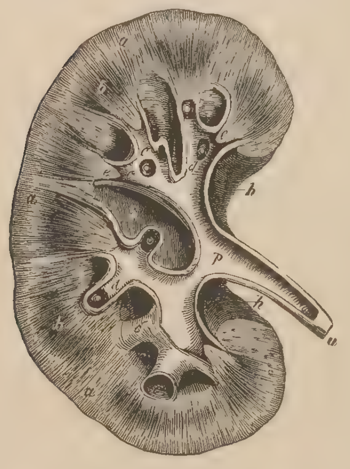


FIG. 195.—PLAN OF A LONGITUDINAL SECTION THROUGH THE PELVIS AND SUBSTANCE OF THE RIGHT KIDNEY. One-half natural size.

a, the cortical substance; *b*, *b*, broad part of two of the pyramids of Malpighi; *c*, *c*, the divisions of the pelvis, named calyces, laid open; *c′*, one of these unopened; *d*, *d*, summit of the pyramids or papillæ projecting into calyces; *e*, *e*, section of the narrow part of two pyramids near the calyces; *p*, pelvis or enlarged portion of the ureter within the kidney; *u*, the ureter; *s*, the sinus of the kidney; *h*, the hilum of the kidney.

The external or cortical substance (*a*) is situated immediately within the fibrous tunic, and forms the superficial part of the organ throughout its whole extent to the depth of about 4 mm., and, moreover, sends prolongations inwards (*columnæ renales* [Bertini]) between the pyramids. It is of a nearly uniform light crimson-brown colour, is soft, and easily lacerated in directions vertical to the surface, and is composed mainly of convoluted renal tubules. The medullary portion of the kidney is more dense than the cortical, and is distinctly striated, owing to its bundles of straight and nearly parallel tubules. The bundles are separated from one another towards the outer part of the pyramids by blood-vessels, and they penetrate for a certain distance into the cortex, forming its pars radiata or the medullary rays. Towards the papillæ, the pyramids are of a lighter colour than the cortical substance, but at their bases they are usually purplish and darker.

In some mammals, *e.g.*, the rabbit (fig. 196), the kidney consists of a single pyramid, invested, except at its papilla, by cortical substance. Usually, however, the kidney contains a number of pyramids, each of which with its investing cortical substance forms a renculus. The number of renculi and the extent of their fusion vary greatly in different animals. The finely lobulated kidney of the Cetacea is an extreme illustration of the non-fusion of numerous renculi. In the human subject, the surface of the fetal kidney is more or less lobulated, but

the shallow furrows separating the lobules tend, as age advances, to become filled up and the surface to present a smooth appearance.

It is often assumed that in man the number of papillæ projecting into the calyces minores represents approximately the number of pyramids, but according to R. Maresch ('Ueber die Zahl und Anordnung der Malpighi'schen Pyramiden in der menschlichen Nieren,' *Anat. Anzeig.*, Bd. xii., August 1896), this is far from being the case. Thus in the right kidney of a man thirty-nine years old, there were eight papillæ and thirty-five pyramids, and on the left side nine papillæ and thirty-eight pyramids. It is especially towards the poles of the kidneys that the pyramids exhibit a marked tendency to fuse into a single papilla. In each of the kidneys just

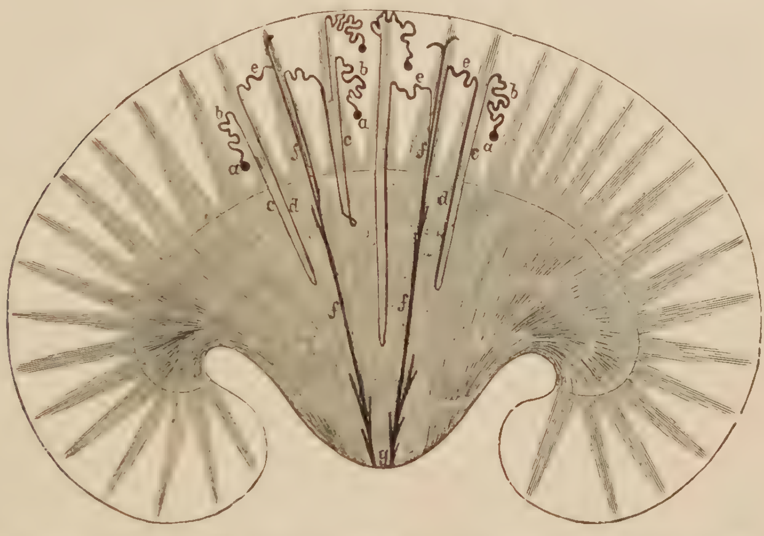


FIG. 196.—DIAGRAM OF THE COURSE OF THE TUBULES IN A UNI-PYRAMIDAL KIDNEY, SUCH AS THAT OF THE RABBIT. (Toldt.)

a, Malpighian bodies ; *b*, first convoluted tubule ; *c*, *d*, looped tubule of Henle ; *e*, second convoluted tubule ; *f*, collecting-tubule ; *g*, placed between two tubules formed by the union of a number of collecting-tubules which open at foramina papillaria on the surface of the pyramidal papilla.

mentioned, nine pyramids, situated at the upper end, ended in one papilla. It is obvious that many of the columns of Bertini are of a secondary or rudimentary type, and only separate adjacent pyramids at their base.

The proper substance of the kidney consists of long but very small branching tubules (*tubuli renales*), which commence as dilated and invaginated capsules covering capillary tufts of blood-vessels (*glomeruli*). The capsules and glomeruli form the *corpuscula renis* [Malpighii], which lie in the cortex of the kidney. After a complicated course, the renal tubules terminate by opening on the free surface of the papillæ of the pyramids. On squeezing a fresh kidney which has been slit open, a little urine will be seen to drain from the papillæ by the fine orifices of the collecting urinary tubules into the terminal divisions of the ureter. About twenty to thirty of these orifices are present on the papillary surface of each pyramid of the adult kidney.

Blood-vessels.—The kidneys are highly vascular, and receive their blood from the renal arteries, which are very large in proportion to the size of the organs they supply. Each renal artery divides into four or five branches, which, passing in at the hilum, between the vein and ureter, may be traced into the sinus of the kidney, where they lie amongst the calyces, together with which they are usually embedded in a quantity of fat. Penetrating the substance of the organ between the papillæ, the arterial branches enter the cortical substance which intervenes between the

pyramids, and proceed in this, accompanied by a sheathing of areolar tissue, and dividing and subdividing, to reach the bases of the pyramids, where they form *arterial arches* between the cortical and medullary parts, which, however, are not complete, and in this respect differ from the freely anastomosing *venous arches* which accompany them. From the arches, peripheral branches (*arteriæ interlobulares* (fig. 199, *ai*)) are given off, which pass outwards between the medullary rays and amongst the convoluted tubules, pursuing a nearly straight course towards the surface of the organ. As they proceed, they give off at intervals short and usually curved branches (*arteriæ glomerularum*), which proceed without further division to the dilated ends of the renal tubules. Within the capsule, the small artery (*vas adferens*) breaks up into a larger number of capillary vessels, which have a convoluted arrangement, and are closely held together by connective tissue to form a spheroidal vascular tuft called the *glomerulus*. A vein (*vas efferens*), smaller than the artery, emerges from the glomerulus close to the point where the artery enters; but, instead of joining with other small veins to form larger venous trunks, as is the case in other organs, the efferent vessel divides into branches after the manner of an artery, and from these arises a dense network of capillaries which everywhere ramify over the walls of the uriniferous tubules (fig. 199), the meshes of the network being polygonal amongst the convoluted tubules and elongated amongst the tubules of the medullary rays. But the efferent vessels from the lowermost glomeruli break up wholly into pencils of straight vessels (*pseud-arteriæ rectæ*) (fig. 199, *vr*), which pass directly into the boundary layer of the medulla, and there supply the continuation downwards of the medullary rays into the pyramid.

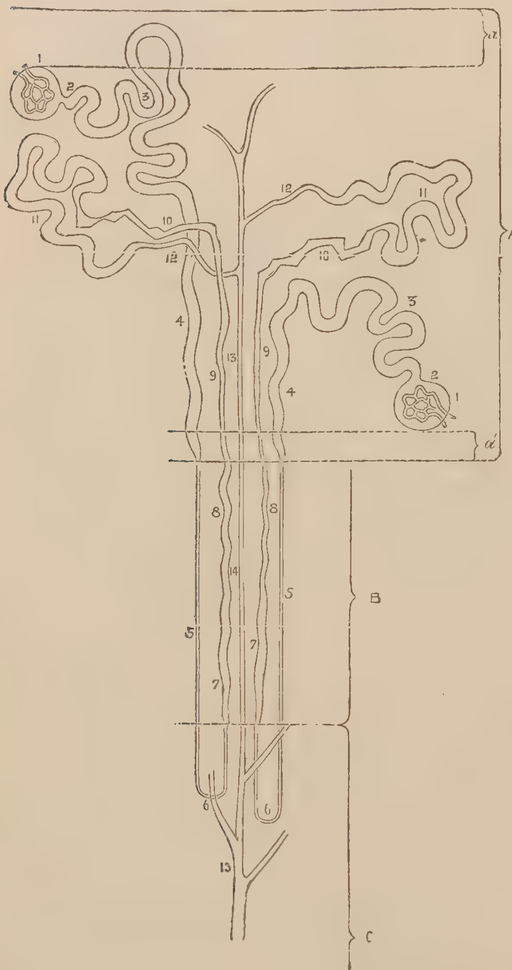


FIG. 197.—DIAGRAM OF THE COURSE OF TWO URINIFEROUS TUBULES. (Klein.)

A, cortex; B, boundary, zone C, papillary zone of the medulla; *a*, *a′*, superficial and deep layers of cortex, free from glomeruli.

1, corpusculæ renis [Malpighii]; 2, neck of tubule; 3, first convoluted tubule; 4, first spiral tubule; 5, descending part of the looped tubule of Henle; 6, loop of Henle; 7, 8, and 9, ascending part of looped tubule of Henle; 10, zigzag tubule; 11, second convoluted tubule; 12, junctional tubule; 13, 14, 15, straight or collecting-tubules; several collecting-tubules unite to form a tubule, which opens on the papilla of a pyramid.

The renal arteries give branches likewise to the capsule of the kidney, which anastomose with branches of the lumbar arteries, and that so freely that Ludwig was able partially to inject the kidneys of a dog from the aorta after the renal arteries had been tied.

The blood is conveyed from the cortex of the kidney by veins (*venæ interlobulares*), which accompany the interlobular arteries, and join the convex side of the venous arches which lie between the medulla and cortex, and also by veins which lie close beneath the capsule of the organ, and take origin by the convergence of minute venous radicles, so as to present a stellate appearance (*venæ stellulæ*). These vessels, which receive blood from the capsule of the kidney, pass inwards through the cortex and also join the venous arches.

With the exception of the blood brought by the false arteriæ rectæ, the blood-supply of the medulla is to a great extent independent of that of the cortex, although of course the capillary network is continuous throughout. The pyramids are chiefly provided with blood by branches which come off directly from the concave side of the arterial arches, and passing down into the boundary layer of the medulla there divide to form bunches or pencils of parallel or slightly diverging minute vessels (*arteriæ rectæ*, fig. 199, *ar*), which, by alternating with the bundles of uriniferous tubules which are passing up to the cortex to form the medullary rays, produce the characteristic streaked appearance of this part of the pyramid (see fig. 198).

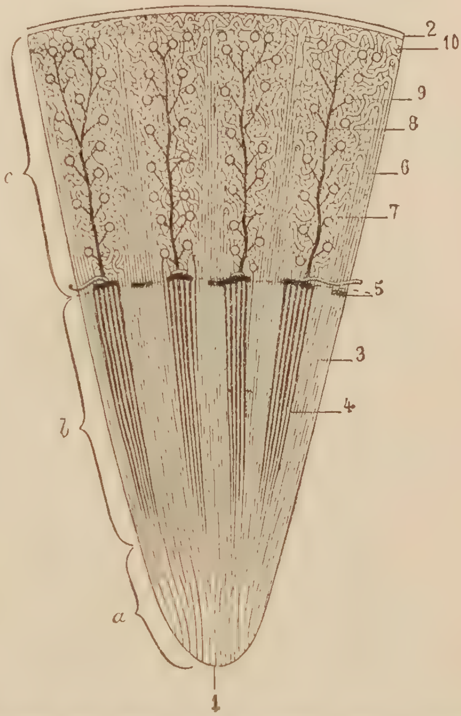


FIG. 198.—DIAGRAM OF A SECTION THROUGH PART OF THE KIDNEY PARALLEL TO THE COLLECTING-TUBULES. (Testut.)

a, papillary zone; *b*, boundary zone; *c*, cortical zone.

1, apex of papilla; 2, capsule; 3, clear striæ of boundary zone formed by bundles of collecting-tubules of pyramid; 4, dark striæ of boundary zone formed by vasa recta; 5, vascular arches; 6, medullary rays formed by collecting-tubules in cortex; 7, labyrinth of convoluted tubules; 8, interlobular vessels; 9, corpuscula renis [Malpighii]; 10, sub-capsular layer.

The long-meshed capillary network which is supplied by the arteriæ rectæ is continued down to the apex of the papilla. Here the veins of the pyramid commence in a close plexus of small venous radicles surrounding the excretory ducts near their orifices (fig. 199, *rp*). Passing outwards towards the base of the pyramid, and receiving lateral branches at acute angles from its capillary network, the same veins become collected together into pencils, the vessels of which (*venæ rectæ*) are intermixed with the arteriæ rectæ, and unite into vessels which open into the concave side of the venous arch.

The venous trunks thence proceed, in company with the arteries, through the renal columns at the sides of the pyramids, to the sinus of the kidney, and around the necks of the calyces form a second anastomosis (Max Broedel). Joining together, they escape from the hilum, and ultimately form a single vein, which lies in front of the artery, and ends in the inferior vena cava.

The branches of the renal artery are terminal, while the veins anastomose freely, so that if one of the branches of the renal artery be injected, only the area of the kidney supplied by it will be injected, while from one of the veins the injection will extend throughout the whole kidney.

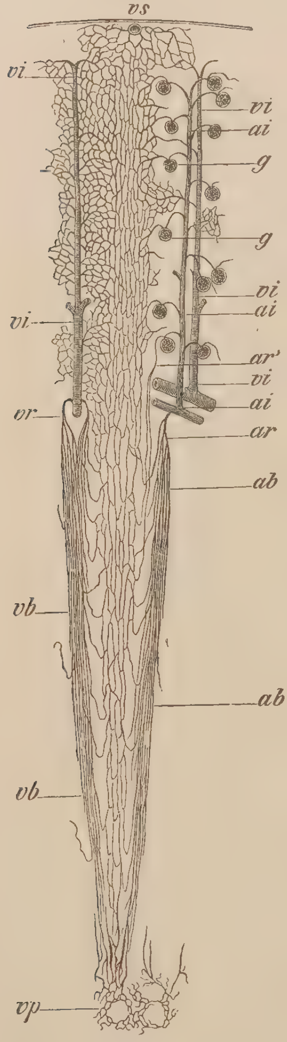


FIG. 199.—DIAGRAM OF THE DISTRIBUTION OF BLOOD-VESSELS IN THE KIDNEY. (From Ludwig.)

ai, ai, interlobular arteries; *vi, vi*, interlobular veins; *g*, a glomerulus; *vs*, stellate vein; *ar, vr*, arteriæ et venæ rectæ forming pencil-like bundles, *ab, vb*; *vp*, venous plexus in the papillæ.

According to Max Broedel ('Intrinsic Blood-vessels of the Kidney and their Significance in Nephrotomy,' *Proc. Assoc. American Anatomists*, 1900), the intrinsic arteries divide in the sinus into dorsal and ventral branches, and the ventral are distributed to the ventral pyramids and the ventral part of the dorsal pyramids, the dorsal branches supplying simply the dorsal halves of the dorsal pyramids. The plane between these two systems of arteries is directed from the outer part of the dorsal surface towards the sinus, and it is along this plane that the kidney can be incised with the least amount of hæmorrhage.

Lymphatics.—The lymphatics of the kidney are numerous, consisting of a superficial set forming a plexus in the fibrous tunic, and of deep lymphatics which issue from the hilum with the blood-vessels. Ludwig and Zawarykin showed that there exists a network of freely intercommunicating lymphatic spaces between the tubules, in communication both with the lymphatics of the surface and those which issue with the blood-vessels at the hilum. They are most abundant in the cortical substance. The lymphatic vessels terminate in the aortic glands.

Nerves.—The nerves which have been traced into the kidneys are small. They come immediately from the *renal plexus* and the *lesser splanchnic* nerves, and contain filaments derived from both the sympathetic and cerebro-spinal systems. The spinal branches are derived from the tenth, eleventh, and twelfth thoracic. The nerves may be traced accompanying the arteries as far as their finer branches, and some fibrils ramify over and amongst the renal tubules, but it is uncertain how they end.

CALYCES, PELVIS, AND URETER.

The tubes which convey the urine from the termination of the urinary tubules at the apices of the renal pyramids to the bladder consist in each kidney of the **calyces renales minores** and **majores**, the **renal pelvis**, and the **ureter.**

The **calyces renales minores**, generally about nine in number, are expanded at their renal ends, where they embrace one or more renal papillæ; while below, they join the major calyces, either directly, when they are sessile, or by a short narrow stalk. Both of these varieties may be attached to the same major calyx. The

great majority of the minor calyces are either dorsal or ventral, and, consequently, turn either forwards or backwards to join the major calyces; but there is often at least one which is directed inwards and lies in a sagittal plane, passing from the hilum to the outer border of the kidney. The greatest distance between the dorsal and ventral calyces minores is 1·1 cm. to 1·5 cm., and that between the most cranial and the most caudal calyx minor is from 5·5 cm. to 6·8 cm.[1]

The **calyces renales majores** are usually two in number—an upper and a lower. The upper is usually the narrower and almost vertical in direction, passing downwards and only slightly inwards, while the lower is generally shorter and thicker than the upper and nearly horizontal in direction.

The **pelvis renalis** is formed in the sinus of the kidney by the union of the two major calyces. It issues from the hilum of the kidney behind the renal vessels, and, curving inwards and downwards, ends at the inner border of the kidney about half-way between the hilum and the lower pole of the kidney by becoming continuous with the ureter. Viewed from the front or behind, it is funnel-shaped, with base above; or its form may be compared to the bowl of a pipe. When empty, its anterior and posterior walls are in contact.

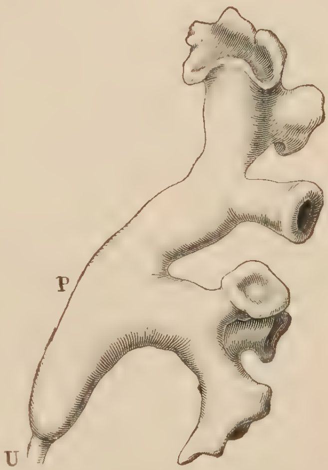


FIG. 200.—CAST OF THE INTERIOR OF THE CALYCES AND PELVIS, AND OF THE UPPER END OF THE URETER. (Henle.)

P, pelvis; U, ureter.

Varieties of the calyces and pelvis.—The calyces minores may vary in number from six to fourteen, the smaller number indicating that some of the calyces minores embrace the apices of several pyramids. As already mentioned, they may be sessile or pedunculated. The variations in the calyces majores and pelvis are more marked. The calyces majores may pass downwards for some distance beyond the hilum, and end by joining to form the ureter without undergoing any obvious expansion. In such cases, the pelvis is absent; or if the calyces dilate below, two pelves may be present. On the other hand, the calyces minores may open into a common expansion, which ends below in the ureter, so that the calyces majores are absent (for further particulars, consult Hyrtl, *Das Nierenbecken der Saugetiere und des Menschen*, Wien, 1870; Lequeu, 'L'anatomie chirurg. du bassinet et l'exploration interne du rein,' *Ann. de Guyon*, 1891; and E. Hauch, 'Ueber die Anatomie und Entwickelung der Nieren,' *Anat. Hefte*, Heft 69, 1903.

Capacity of pelvis and calyces.—This can be estimated in the living body by injecting fluid into the pelvis through a ureteric catheter until the patient complains of pain. Thomson Walker[2] found the average capacity to be 5 c.c. to 7 c.c. Kerr, from measurements of casts of the pelvis and calyces, considers the average to be 8·6 c.c. A capacity of 15 c.c. or upwards indicates abnormal dilatation (hydronephrosis).

The ureter.—Towards the lower part of the sinus of the kidney, or a little below the sinus, the renal pelvis contracts, either gradually or abruptly, and, assuming a cylindrical form, receives the name of ureter. This duct conveys the urine from the pelvis to the bladder.

Dimensions.—The ureter measures, on an average, in an adult male about 30 cm. (12 inches). It is about 2 cm. to 3 cm. shorter in the female, and the left ureter is generally 1 cm. to 2 cm. longer than the right. They are extensile, so that after removal from the body they can easily be stretched 2 cm. to 3 cm. When

[1] R. A. Kerr, 'The Form and Capacity of the Adult Renal Pelvis,' *Trans. Ulster Medical Society*, Session 1912–13.

[2] 'Pyelography and the Early Diagnosis of Dilation of the Kidney,' *Lancet*, June 17, 1911.

examined *in situ*, the ureter usually appears as a flattened tube, but it may be round —probably as the result of a contracted condition of the muscular coat. According to the researches of G. Schwalbe,[1] based upon injections, the abdominal part of the ureter forms a long spindle, the middle of which may have double the diameter (8 mm.) of the two ends. After crossing the pelvic brim, the ureter has one or two dilatations, but as a rule they are not so marked as the one in the abdomen. Bougies of about 2 mm. in diameter are usually employed in its catheterisation. The narrowest part of the ureter, except its vesical orifice, is that contained in the walls of the bladder.

Course and relations.—The ureter descends on the posterior wall of the abdomen, and then crosses the iliac vessels to reach the pelvis, in which it at first

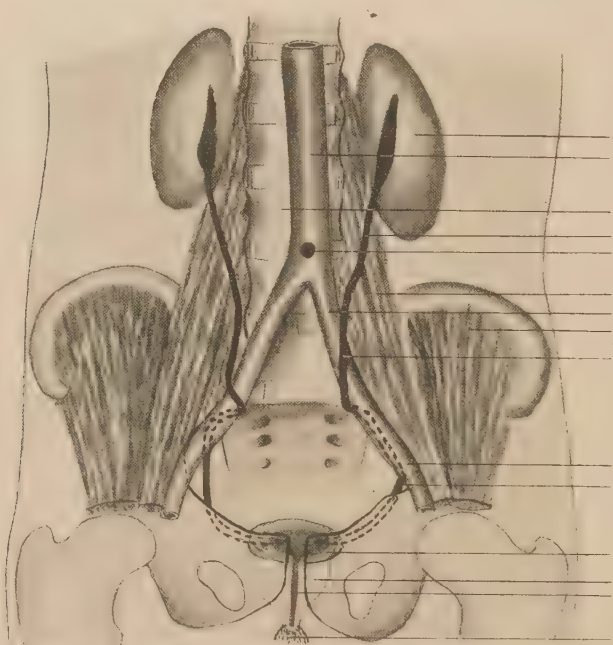


FIG. 201.—RECONSTRUCTION OF THE COURSE OF THE URETERS, MADE FROM A SERIES OF HORIZONTAL SECTIONS OF A MAN, AGED SIXTY-EIGHT YEARS. About one-fourth natural size. (J. Symington.)

Where the ureters are concealed in a view from the front by the iliac vessels and the anterior pelvic wall their course is indicated by dotted lines.

lies against the lateral wall, and then curves forwards and inwards to the bladder. In nearly the whole of its course, it lies just beneath the peritoneum, to which it is united by areolar tissue ; so that when the peritoneum is stripped off the posterior abdominal wall, the ureter comes away with the peritoneum. It may be divided into an abdominal and a pelvic portion. The abdominal part passes downwards and somewhat inwards on the psoas muscle, and is crossed obliquely, from without inwards, by the spermatic or ovarian vessels, while the genito-femoral nerve is behind it. The right ureter, at its origin, is behind the duodenum, and, as it descends, it approaches the inferior vena cava and sometimes gets in front of it. The left ureter lies a little to the left of the abdominal aorta, and is crossed by the left colic and sigmoid branches of the inferior mesenteric artery. The ureter leaves the

[1] 'Zur Anatomie der Ureteren,' *Verh. d. Anat. Gesellschaft*, 1896.

psoas muscle by passing from without inwards over the lower end of the common iliac vessels or the upper end of the external iliacs. Near the brim of the pelvis, the right ureter may be crossed by the termination of the ileum, and the left by the pelvic colon. In the pelvis, the relations of the ureter differ according to the sex.

In the *male*, the ureter descends on the side wall of the pelvis, covered on its median aspect by the peritoneum, and having lateral to it the hypogastric blood-vessels. Its course is a curved one, being first directed downwards and backwards, and then forwards and downwards. This part of the ureter is about 10 cm. to 12 cm. in length, and may be termed *parietal*. As it approaches the bladder it is crossed by the ductus deferens, and then goes onwards as the *vesical* portion, which is divisible into an extra-mural and an intra-mural part. The *extra-mural* part lies

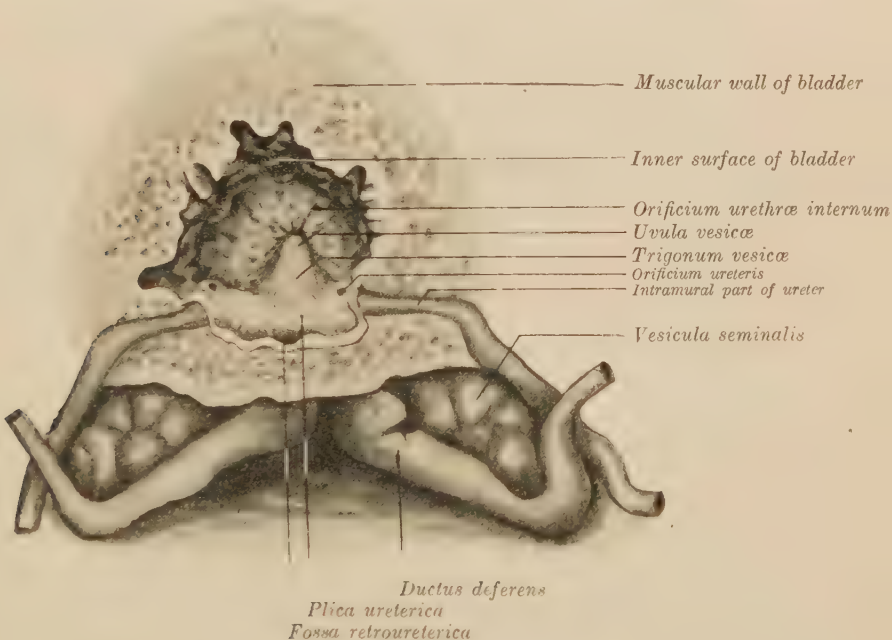


FIG. 202.—VIEW OF THE EXTRA-MURAL AND INTRA-MURAL PORTIONS OF THE VESICAL PART OF THE URETER. Natural size. (J. Symington.)

above the seminal vesicle, and is closely related to the vesical plexus of veins, which vessels are situated mainly above and lateral to it. After a course of one or two centimetres, it passes obliquely through the bladder wall as the *intra-mural* part (see fig. 202), and terminates at the *orificium ureteris*.

In the *female*, the pelvic portion of the ureter may be divided into parietal and visceral. The parietal portion resembles that of the male in its general course and in its relations to the peritoneum, but it usually forms the posterior and lower boundary of a fossa for the ovary (see fig. 110). The visceral portion is longer than in the male, and lies in relation to the uterus and vagina as well as the bladder. It begins a little in front of the lower boundary of the ovarian fossa, and at the base of the broad ligament passes forwards and downwards, lateral to the supra-vaginal part of the cervix uteri. The uterine artery, surrounded by a plexus of veins, turns inwards at this level, above the ureter, to reach the cervix. The ureter is about 15 mm. lateral to the cervix, but the distance may be increased or diminished by lateral displacement of the uterus. The ureter next passes near the lateral

fornix of the vagina to gain the interval between the vagina and bladder. It reaches the anterior vaginal wall about the level of the lower edge of the anterior lip of the os uteri and ends, as in the male, by piercing obliquely the wall of the bladder.

FIG. 203.—SECTION ACROSS THE UPPER PART OF THE URETER. Magnified fourteen diameters. (v. Ebner.)

e, epithelium ; *s*, mucous membrane ; *l*, longitudinal muscle ; *r*, circular muscle.

Structure.—The walls of the calyces, pelvis, and ureter consist of an external fibrous coat, a middle coat of plain muscular tissue, and a mucous lining. The

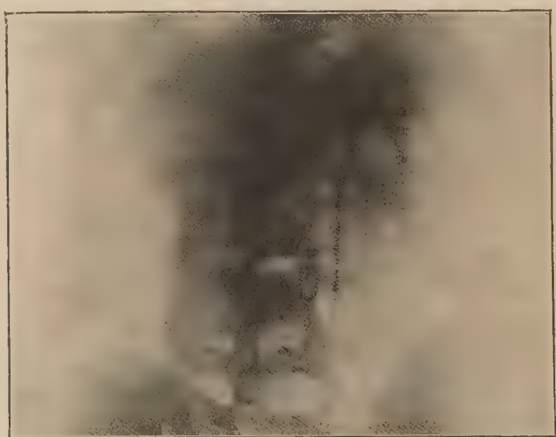


FIG. 204.—SKIAGRAM TAKEN DURING LIFE OF LEFT RENAL PELVIS AND ABDOMINAL SEGMENT OF URETER. (J. W. Thomson Walker.)

An opaque catheter lies in this ureter, and the renal pelvis and calyces are filled with collargol solution. The collargol solution is commencing to distend the ureter and has reached down to the level of the third lumbar vertebra. The line of the ureter is seen passing straight into that of the pelvis, and by a gentle curve, into the upper calyx major, also the wide angle formed by the lower calyx major and the pelvis.

muscular coat possesses two layers of longitudinal fibres and a middle circular layer.

The mucous membrane, thin and smooth, presents a few longitudinal folds when the ureter is laid open. There is no marked distinction between the mucous and

submucous layers. As the ureter traverses the bladder wall, it retains its independence, and is separated from the muscular coat of the bladder by a layer of connective tissue. Just outside the bladder, the ureter is ensheathed by a mass of longitudinal muscular fibres forming the ureter-sheath of Waldeyer.

Blood-vessels, lymphatics, and nerves.—The ureter is supplied with blood from small branches of the *renal*, the *spermatic*, the *hypogastric*, and the *inferior vesical* arteries. The veins end in various neighbouring vessels. The lymphatic vessels form a network in the mucous, submucous, muscular, and fibrous coats, and the afferent vessels end in the aortic, inter-iliac, and hypogastric glands. The nerves come from the *inferior mesenteric, spermatic*, and *hypogastric plexuses*. They form plexuses in the outer and muscular coats, containing a few ganglion-cells.

Varieties.—The variations in the calyces and pelvis have already been mentioned. The principal variation in the ureter is a more or less complete division into two. As a rule, the two ureters unite a little above the bladder, so that there is only one vesical orifice; but the division may be complete, *i.e.* with two separate openings into the bladder. A. T. Kerr ('Double Ureter in Man,' *Anat. Record*, vol. v., 1911) has described five cases of this kind.

In rare cases, a triple ureter has been met with. Several instances are recorded in which a supernumerary ureter, proceeding from the upper part of the kidney, opened directly into the urethra.

The right ureter has been seen passing behind the inferior vena cava, and then turning forwards between that vessel and the aorta (Hochstetter, *Morph. Jahrb.*, Bd. xxi., s. 636; and Gladstone, *Jour. Anat. and Phys.*, vol. xlv., April 1911).

In instances of long-continued obstruction to the passage of the urine, the ureters may become enormously dilated.

VESICA URINARIA.

The urinary bladder (vesica urinaria) is a hollow receptacle for the urine, having an average capacity, when moderately filled, of about 500 c.c., but capable of being distended to a considerably greater degree. It receives the urine by the two ureters, and discharges it through the urethra.

The average capacity of the bladder is often stated to be greater in the female than in the male—and, no doubt, instances of very large female bladders are not infrequent; but these have probably been the result of unusual distension: in the natural condition, according to Luschka and Henle, the female bladder is decidedly smaller than that of the male.

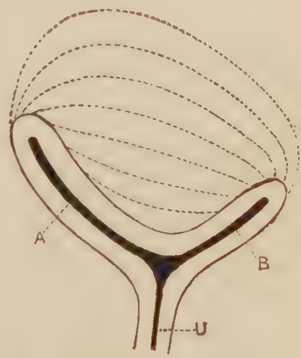


Fig. 205.—Diagram of median section of empty diastolic bladder and adjacent part of urethra. (J. Symington.)

A, anterior limb of bladder; P, its posterior limb; U, urethra. The dotted lines show the changes in the shape of the bladder during its distension.

The shape, position, and size of the bladder, and its relations to neighbouring parts, vary according to the degree of distension of its cavity; and also, when empty, according to the condition of its muscular coat, whether contracted or relaxed. When empty and relaxed (in diastole), it lies deeply in the pelvis; and in a vertical median section its cavity, with that of the adjacent portion of the urethra, is Y-shaped, the stem of the Y being formed by the urethra, and its two limbs by the bladder. Of the two limbs, the *anterior* is the longer, and is directed upwards and forwards; while the shorter *posterior* limb passes backwards and upwards. The superior surface of this type of bladder is concave, and covered by peritoneum. On the other hand, when the bladder is empty and contracted—as it is frequently found to be in formol-hardened subjects—the two limbs of its cavity are much shortened, its mucous

membrane is thrown into numerous folds, its muscular coat is greatly thickened, and its superior aspect is convex.

The bladder then forms a flattened inverted tetrahedron[1]—this shape being due to the fact that the four points where the two ureters, the urachus, and the urethra join the organ are more firmly fixed in position than other parts of the bladder wall. As the organ contracts upon itself during micturition, these four points are more or less held apart, and so become the four angles of a tetrahedron. The surfaces of the bladder are superior, basal, and two infero-lateral. The

FIG. 206.—LATERAL VIEW OF THE VISCERA OF THE MALE PELVIS. One-fourth natural size. (R. Quain.)

The left hip-bone has been disarticulated from the sacrum, the spinous process of the ischium cut through, and the pubis divided to the left of the symphysis. *a*, bladder; *b*, *b′*, rectum; *c*, membranous part of the urethra; *d*, section of the left corpus cavernosum; *e*, bulb of the cavernous body of the urethra; *f*, Cowper's gland; *g*, section of the body of the pubis; *h*, sphincter ani muscle; *i*, part of the left ductus deferens; *m*, articular surface of the sacrum; *n*, divided spine of the ischium; *o*, coccyx; *p*, prostate gland; *r*, *r*, peritoneum; *r′*, recto-vesical pouch; *u*, left ureter; *v*, left vesicula seminalis.

superior surface is triangular, convex, and covered by peritoneum. It is bounded by two rounded lateral borders, which converge anteriorly towards the apex of the bladder, and by a posterior border separating it from the base. Some convolutions of the jejuno-ileum, and often also the pelvic colon, rest upon this surface, and, in the female, the body of the uterus overlaps it posteriorly. The *basal surface* is triangular, with its apex towards the urethral orifice. In the male it is separated from the rectum by the seminal vesicles and the ampullary portions of the ductus deferentes, and in the female it lies against the cervix uteri and the upper part of the anterior vaginal wall. The *infero-lateral surfaces* are directed towards the pelvic floor, and look downwards and outwards. They are separated from one another by a median ridge passing from the apex of the bladder towards the urethral orifice. They rest upon the pubes, the retro-pubic pad of fat, and the pelvic fascia, separating them from the levatores ani. Around the urethral orifice, the male bladder rests upon the prostate gland.

As the empty bladder is gradually filled with urine, it expands—chiefly in an upward direction; but it also bulges outwards towards the side wall of the pelvis,

[1] A. F. Dixon, 'The orm of the Empty Bladder,' *Jour. Anat. and Phys.*, vol. xxxiv., January 1900.

backwards towards the rectum, and, to a less extent, downwards, by depressing the pelvic floor.

When moderately filled, it is still contained within the pelvic cavity, and has a rounded form (fig. 206, *a*); but when completely distended, it rises above the

FIG. 207.—VERTICAL MEDIAN SECTION OF THE PELVIS OF AN ADULT MALE SUBJECT. Half-natural size. (Braune.)

1ST S, body of first sacral vertebra; P.S., pubic symphysis; Bl., bladder; R. R. R. rectum; P. P. prostate; P′, middle lobe of prostate; F, retro-pubic pad of fat; Bu., bulb; P.C., peritoneal cavity; J.I., convolutions of jejuno-ileum.

brim of the pelvis, and becomes egg-shaped: its larger end, which is called the *base*, or *fundus*, being directed downwards and backwards towards the rectum in the male and the vagina in the female; and its smaller end, or *vertex*, resting against the lower part of the anterior wall of the abdomen. Immediately in front of the base, is the portion which joins the urethra, and is often named the *cervix* or *neck*. When the bladder is excessively distended (fig. 208), it may rise into the abdomen nearly as high as the umbilicus, and it also sinks somewhat in the pelvis,

pushing the prostate and lower end of the rectum downwards and backwards. The long axis of the distended bladder varies in different cases, being modified by the degree of distension of the bladder itself, as well as that of the rectum and other portions of the intestine that may be in relation with it. In a section of Braune's (see fig. 207), in which the bladder was moderately distended, it is almost horizontal, while in one by Rüdinger (see fig. 208), in which the bladder was greatly distended, it is rather more nearly vertical than horizontal. While in the male, the longest diameter of the moderately distended bladder is directed from its base to its summit, in the female the transverse diameter is the longest.

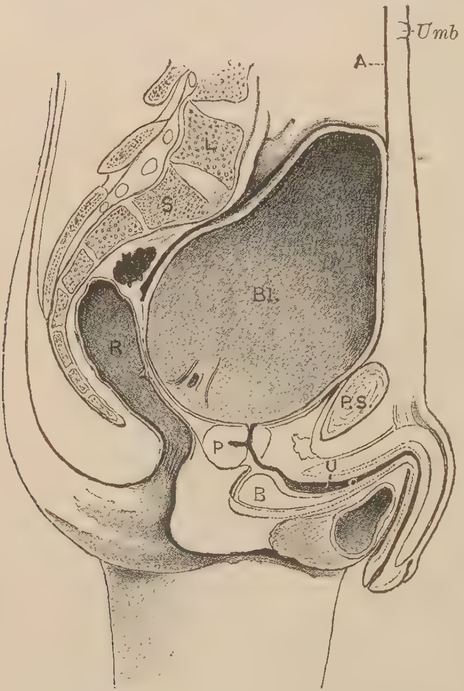


Fig. 208.—Median section of the pelvis of an adult male subject. (Rüdinger.)

L. body of fifth lumbar vertebra; S, body of first sacral vertebra; P, S, pubic symphysis; P, prostate; B, bulb; U, urethra; *Umb*, umbilicus; A. peritoneum. The reflexion of the peritoneum from the anterior abdominal wall on to the bladder is higher than normal.

One of the most fixed points of the bladder is its urethral orifice. This lies a little below (say, on an average, 5 mm.) the level of a horizontal line, prolonged backwards from the upper border of the pubic symphysis, and is about 6 cm. behind the upper end of the long axis of the pubic symphysis. It can therefore be easily reached with the index-finger, after cutting through the anterior abdominal and bladder walls. Disse [1] gives its average distance from the conjugate of the pelvic inlet as about 5 cm. in the male, and 6 cm. in the female. The orifice is pushed upwards and forwards by distension of the lower end of the rectum, [2] is depressed during the filling of the bladder, and is probably higher in stout than in thin subjects.[3] The distance of the bladder from the surface of the perineum largely depends on the size of the prostate gland, and especially on the thickness of the pelvic floor (see figs. 209 and 210).

Lichtenberg and Volcker ('Die Form der menschlichen Blase,' *Verh. der Anat. Gesell. Genf.*, 1905) filled the bladder during life with a 2 per cent. solution of collargol, and took skiagrams from the front. They found that in the coronal plane, the broad end of the bladder was directed upwards and the narrow one downwards into the pelvis.

Connexions.—While freely movable in other directions, the bladder is fixed below to the prostate, its mucous and muscular coats being here continuous with those of the prostatic portion of the urethra, while the fibrous investments of the bladder and prostate are attached to the anterior and lateral walls of the pelvis by the true ligaments of the bladder.

[1] 'Untersuchungen ueber die Lage der menschlichen Harnblase und ihre Veränderungen im Laufe des Wachstums,' *Anat. Hefte*, Heft i., 1892.

[2] Garson, 'Die Dislocation der Harnblase und des Peritoneum bei Ausdehnung des Rectum,' *Arch. f. Anat.*, 1878.

[3] Symington, 'A Comparison of the Pelvic Viscera and the Pelvic Floor in Two Adult Male Subjects,' *Jour. Anat. and Phys.*, vol. xxxiv., Oct. 1899.

It is supported, moreover, by strong areolar connexions with the rectum and prostate, or uterus and vagina (according to the sex), in a slighter degree by the two ureters, the lateral umbilical ligaments, the urachus, and by numerous blood-vessels, and, lastly, by a partial covering of the peritoneum, which, in being reflected from this organ in different directions, forms duplicatures, named the *false ligaments* of the bladder.

As the empty bladder becomes filled, its **infero-lateral surfaces** extend upwards on the anterior wall of the pelvis, and then on to the lower part of the anterior abdominal wall. This movement is facilitated by the looseness of the areolar tissue found superficial to this aspect of the bladder. The space occupied by this tissue is sometimes termed the *cavum prævesicale*, or *cavum Retzii*.

As, during distension, the bladder rises more rapidly than the peritoneum is detached from the back of the pubes and the anterior abdominal wall, a peritoneal pouch, gradually increasing in depth, is formed in front of the upper part of the bladder. It is generally estimated that, even in extreme distension, the bladder is seldom uncovered by peritoneum for more than 5 cm. above the pubic symphysis.

The **superior or abdominal surface** is entirely free, and covered everywhere by the peritoneum. When the bladder is empty, this surface looks mainly upwards; but as it becomes filled, it tends to be directed backwards, and in the male the small intestines and pelvic colon may be pushed out of the pelvis and the bladder brought into contact with the rectum, while in the female the uterus is moved backwards.

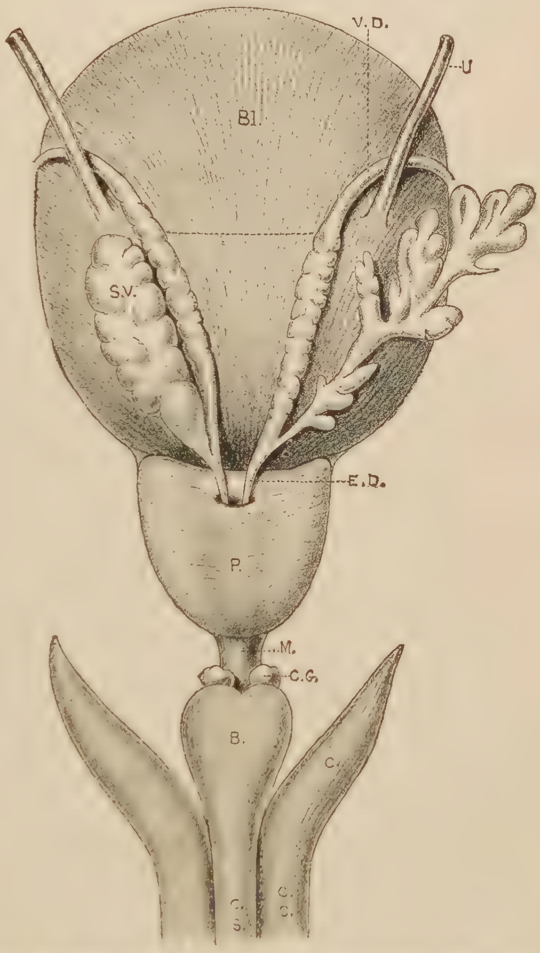


FIG. 209. DIAGRAM OF THE BLADDER, PROSTATE, ETC., IN THE MALE. (J. Symington.)

Bl. part of base covered by peritoneum, separated by a dotted line from a triangular space left uncovered by that membrane; U., ureter; S.V., seminal vesicle; E.D., ejaculatory duct; P., prostate; M., membranous part of urethra; B., bulb; C.S., corpus cavernosum urethræ; C.G., glandula bulbo-urethralis; C., crus penis; C.C., corpus cavernosum penis.

The **lateral borders** of the bladder become obliterated during the distension of the bladder, so that the organ when viewed from the side presents a large convex surface, the upper and posterior part of which is covered by peritoneum, and the lower and anterior uncovered. The ligamentum umbilicale laterale lies some distance lateral to the empty bladder, but, in its distended condition, the ligament

is found passing upwards and forwards, in contact with it, near the line of reflexion of the peritoneum. The ductus deferens crosses obliquely the hinder part of this lateral surface, from before backwards and downwards, and, turning over the lateral umbilical ligament, descends median to the ureter, on the base of the bladder.

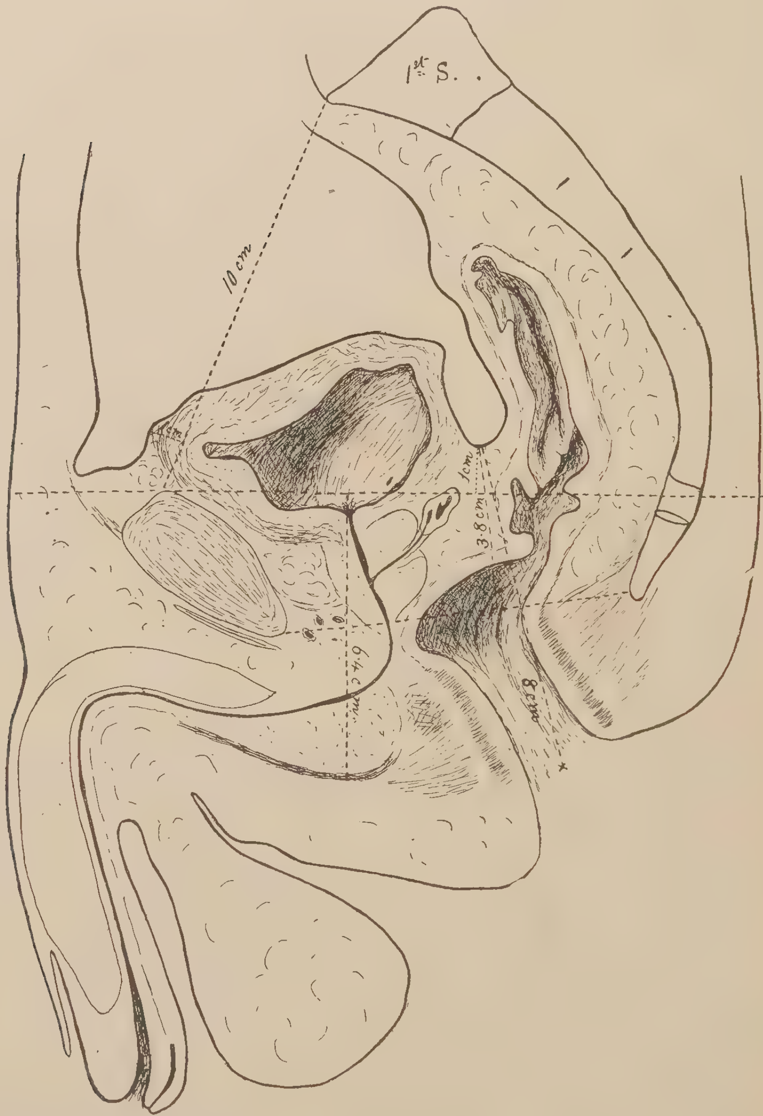


FIG. 210.—MEDIAN SECTION OF THE PELVIS OF A RATHER STOUT MAN, AGED FORTY YEARS, WITH SHALLOW RECTO-VESICAL POUCH, HIGH BLADDER, AND DEEP PELVIC FLOOR. Both this and fig. 211 are reduced to nearly one-half natural size. (J. Symington.)

In the male, the base of the bladder is usually covered by peritoneum as far down as the transverse line, uniting the two ureters, where they pierce the bladder wall. Above this point, the peritoneum forms on the empty bladder a crescentic fold, called *sacro-genital*, and the peritoneal recess below this fold is the *recto-genital*

pouch (see fig. 231). Other transverse peritoneal folds are often seen on the upper aspect of the empty bladder, but these, as well as the recto-genital, are obliterated by distension of the bladder. The peritoneal recess between the rectum and the bladder may be abnormally deep (fig. 211).

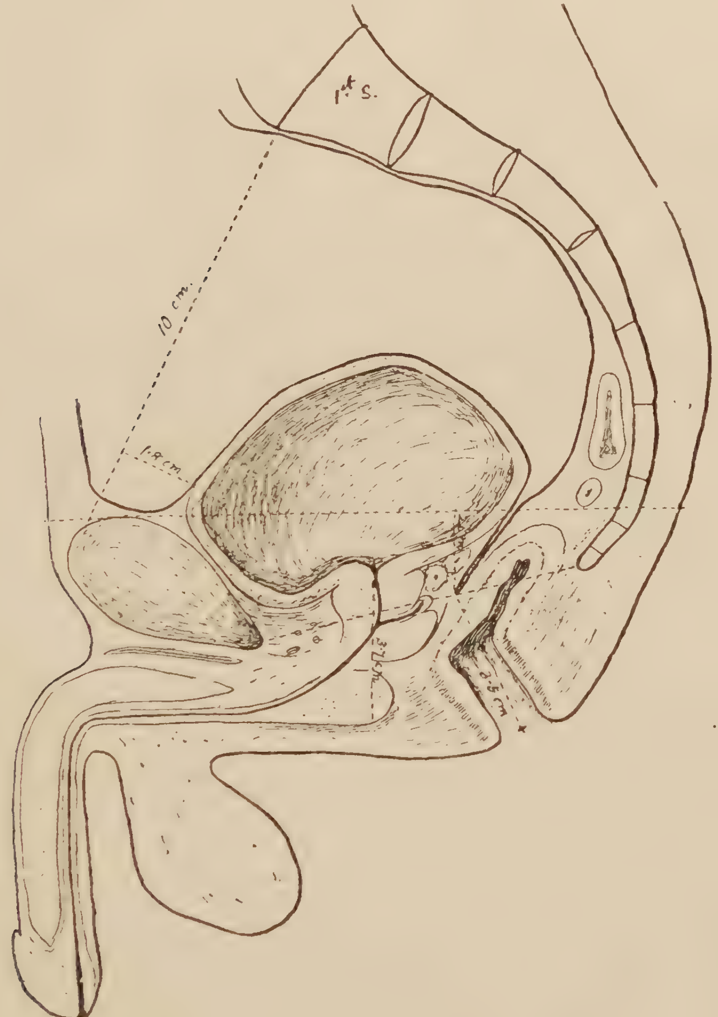


Fig. 211.—Median section of the pelvis of a thin man, aged twenty-seven years, with a deep recto-vesical pouch, a shallow pelvic floor, and a low position of the bladder. (J. Symington.)

In the female, the peritoneum is reflected from the uterus on to the bladder at the junction of the body and cervix of the uterus, so that the surface of the bladder, in relation to the cervix of the uterus and the upper part of the vagina, is uncovered by peritoneum (fig. 259).

The vertex is connected to the anterior abdominal wall by a tapering median cord, named the *urachus*: this is composed of fibrous tissue, mixed at its base with plain muscular fibres, which are prolonged upon it from the bladder. This cord,

becoming narrower as it ascends, passes upwards from the apex of the bladder between the linea alba and the peritoneum, to reach the umbilicus, where it becomes blended with the dense fibrous tissue found in that situation.

The urachus, which forms in the early fetal state a tubular connexion between the urinary bladder and the allantois, preserves—according to Luschka—vestiges of its original condition

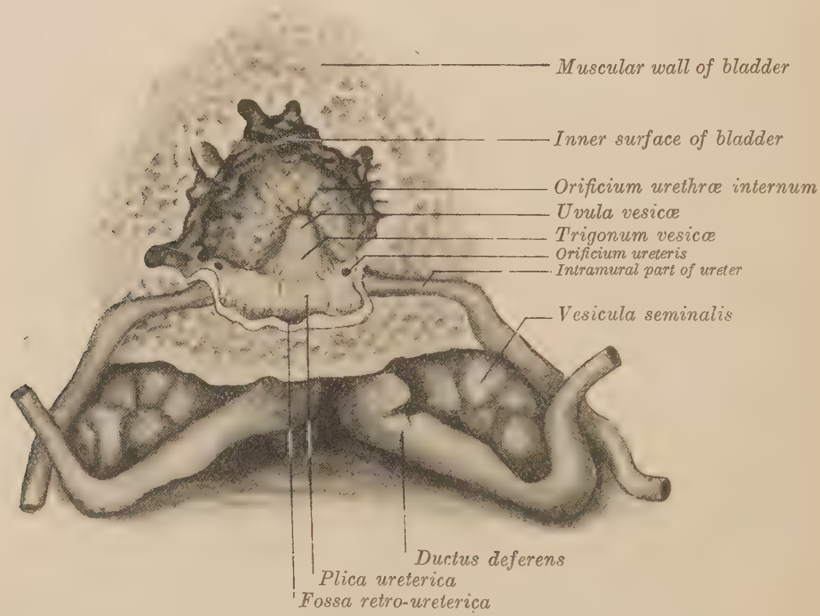


FIG. 212.—VIEW, FROM ABOVE, OF THE INTERIOR OF THE CONTRACTED BLADDER OF AN ADULT MALE. Natural size. (J. Symington.)

in the form of a long interrupted cavity, with irregularities and dilatations, lined with epithelium similar to that of the bladder, and sometimes communicating by a fine opening with the vesical cavity.

Interior of the bladder.—On opening the bladder, its internal surface is found to be lined by a mucous membrane, which is comparatively loosely attached to the other coats, so that in the empty condition of the organ it is nearly everywhere thrown into small wrinkles or rugæ, which disappear as soon as the bladder is distended. Besides these, the interior of the bladder is often marked by reticular elevations or ridges, corresponding to fasciculi of the muscular coat.

At the lower part of the bladder (fig. 212) is seen the orifice leading into the urethra, around which the mucous membrane is corrugated longitudinally. Immediately behind the urethral opening, at the lower part of the fundus, is a triangular surface, having its apex directed forwards, and known as the trigonum vesicæ. The basal angles of this area correspond to the orifices of the ureters, which are oval slits directed forwards and inwards and admitting a catheter about 2 mm. in diameter. These orifices are united by a curved elevation, convex in front, which generally extends outwards and backwards beyond them, and is known as the *plica ureterica*, or Mercier's bar. The mucous membrane of the trigone is firmly adherent to the

subjacent tissue, and presents very fine folds, which radiate outwards and backwards from the urethral orifice. It is rather darker in colour than the rest of the mucous membrane of the bladder. When the bladder is distended, the ureteric orifices are 3 cm. to 4 cm. apart, and nearly the same distance from the urethral orifice; but when the bladder is contracted, they are nearer one another, and the area of the

FIG. 213.—MEDIAN SECTION OF THE PELVIS OF A NEWLY BORN MALE CHILD. (Disse.)

V.l.v., body of fifth lumbar vertebra; *V.s.v.*, body of fifth sacral vertebra; *Sy.*, pubic symphysis; *Rct.*, rectum (distended); *Prt.*, peritoneum; *Bspr.*, prævesical cleft; *Pro.*, placed just below median lobe of prostate; *Lf.*, longitudinal muscular fibres of rectum; 1, sphincter ani int.

trigone is correspondingly diminished. Behind the plica ureterica is a recess called the retro-ureteric fossa. The posterior boundary of the urethral orifice forms a small elevation known as the uvula vesicæ. In the female, the trigone rests on the anterior vaginal wall; it is small and the uvula indistinct.

In a small percentage of cases, the trigone is only slightly evident—even on close examination. In other cases, the downward convexity of Mercier's bar is so acute that it reaches the uvula vesicæ, and the trigone is represented simply by an eminence at this junction (Wright and Benians, 'The Anatomy of the Trigonum Vesicæ,' *Brit. Med. Jour.*, October 15, 1910).

The trigonal part of the bladder is generally considered to have a different developmental origin from the remainder of the bladder, being derived from the mesoderm or excretory (Wolffian) ducts, while the other part is endodermic and cloacal. It is suggested by Wright and Benians that it may be derived from the fusion and opening out of the caudal ends of the two ureters.

Variations in number and position of ureteric openings.—If on cystoscopic examination one of the ureteric openings be absent, it is a strong indication that the kidney of that side is congenitally absent. The presence of two ureteric orifices is not a positive proof that both kidneys are present, for one of the orifices may lead into a blind recess, or, as in a specimen in my department, only one kidney may exist, with two ureters opening into the bladder, one on each side. With the cystoscope, the ureteric orifice can be seen to contract every few seconds and emit a tiny jet of urine (see J. W. Thomson Walker, *The Renal Function in Urinary Surgery*, 1908).

Ectopia vesicæ.—This, the most frequent malformation of the bladder, is characterised by an absence of the anterior abdominal and bladder walls, between the umbilicus and the pubes, so that the posterior wall of the bladder appears on the surface of the abdomen as a soft, red, moist, mucous area, on which can be recognised the two ureteric orifices. It is often combined with epispadias. (For nature of this malformation, consult A. Keith, *British Med. Jour.*, December 26, 1908.)

Peculiarities in shape and position according to age.—In the newly born child, the bladder is much higher than in the adult. Thus, its urethral orifice is at the level of the upper border of the pubic symphysis, and the anterior surface

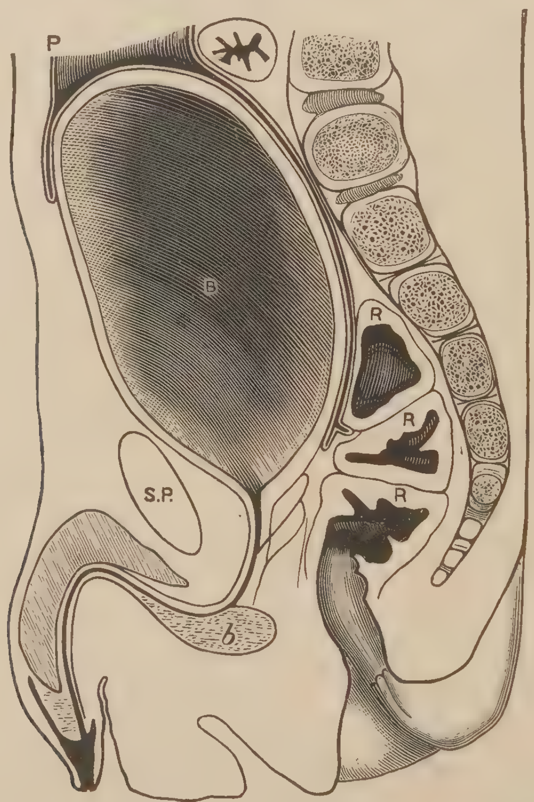


FIG. 214.—MEDIAN SECTION OF THE PELVIS OF A MALE CHILD, AGED SEVEN MONTHS, BLADDER NATURALLY DISTENDED WITH URINE. Natural size. (J. Symington.)

P, peritoneum; S.P., pubic symphysis; B, bladder; R, rectum; *b*, bulb. In this specimen the distance from the umbilicus to the top of the pubic symphysis was 7 cm., and the vertical extent of the bladder in contact with the anterior abdominal wall and uncovered by peritoneum was 3·2 cm.

of the bladder, entirely uncovered by peritoneum, lies against the top of the pubic symphysis and the anterior abdominal wall, opposite about the lower two-thirds of the space between the pubes and the umbilicus (fig. 213). If the bladder be empty, its cavity in a median section shows a long anterior limb passing from the urethral orifice upwards and forwards towards the umbilicus; but there is no indication of a posterior limb—such as has already been described in the adult. If the bladder be distended, it usually has an ovoid form, with the large end of the oval directed downwards and backwards. The peritoneum covers the posterior surface of the bladder in its entire extent, and is reflected from it on to the umbilical arteries at the sides and on to the urachus above.

After birth, the bladder rapidly descends into the pelvis and acquires, when contracted, a rounded instead of a flattened form. In an infant aged three and a half months, in which the bladder was contracted, the distance from the umbilicus to the upper border of the pubes was 4·8 cm., and the bladder reached only 1 cm. above the pubes, or less than one-fourth of the above-mentioned space. The bladder was fully distended by about one ounce of urine in the infant aged seven months (see fig. 214); but there is no large fundus as in fig. 208, and fully one-half of the bladder lies above the plane of the pelvic inlet. The distance between the pubes and the umbilicus is 7 cm., and the bladder reaches within 2 cm. of the umbilicus. In a boy aged three years (see fig. 215), the bladder is contracted and lies almost entirely below the plane of the pelvic inlet, and the peritoneum is reflected from the anterior abdominal wall on to the upper surface of the bladder about 1 cm. above the symphysis pubis. In another boy, aged five years, in whom the bladder was also contracted, the peritoneum passed down on the back of the pubic symphysis before being reflected on to the bladder. Disse made a series of observations on the distance from the urethral orifice of the bladder to the plane of the pelvic inlet, and he came to the conclusion that the bladder sinks rapidly during the first two years, then slowly, until the commencement of the ninth year, when it remains stationary until puberty, at which period it again slowly descends until it gains its adult position. (For further particulars of the bladder in the child, consult Symington, 'The Topographical Anatomy of the Child,' 1887; Takahashi, 'Beiträge zur Kenntniss der Lage der fetalen und kindlichen Harnblase,' *Arch. f. Anat.* 1888; Disse, 'Untersuchungen ueber die Lage der menschlichen Harnblase und ihre Veränderung im Laufe des Wachstums,' *Anat. Hefte*, Heft 1, 1892; and Birmingham, 'The Shape and Position of the Bladder in the Child,' *Jour. Anat. and Phys.*, vol. xxxii., 1898.)

FIG. 215. PART OF A MEDIAN SECTION OF THE PELVIS OF A MALE CHILD, AGED THREE YEARS. Natural size. (J. Symington.)

STRUCTURE OF THE BLADDER.

The bladder is composed of a *serous*, a *muscular*, a *submucous*, and a *mucous* coat, and is supplied with numerous blood-vessels and nerves.

The **serous** or **peritoneal coat** is a partial covering, investing only the posterior and upper half of the bladder, and reflected from it upon the surrounding parts in the manner already described in detail.

The **muscular coat** consists of unstriped muscular fibres, which are described as forming layers, the outer of which consists of bundles of fibres more or less longitudinal, and the next of fibres more circular in disposition; while beneath this is a submucous layer.

The *external longitudinal fibres* (fig. 216, A, B, C) are most distinctly marked on

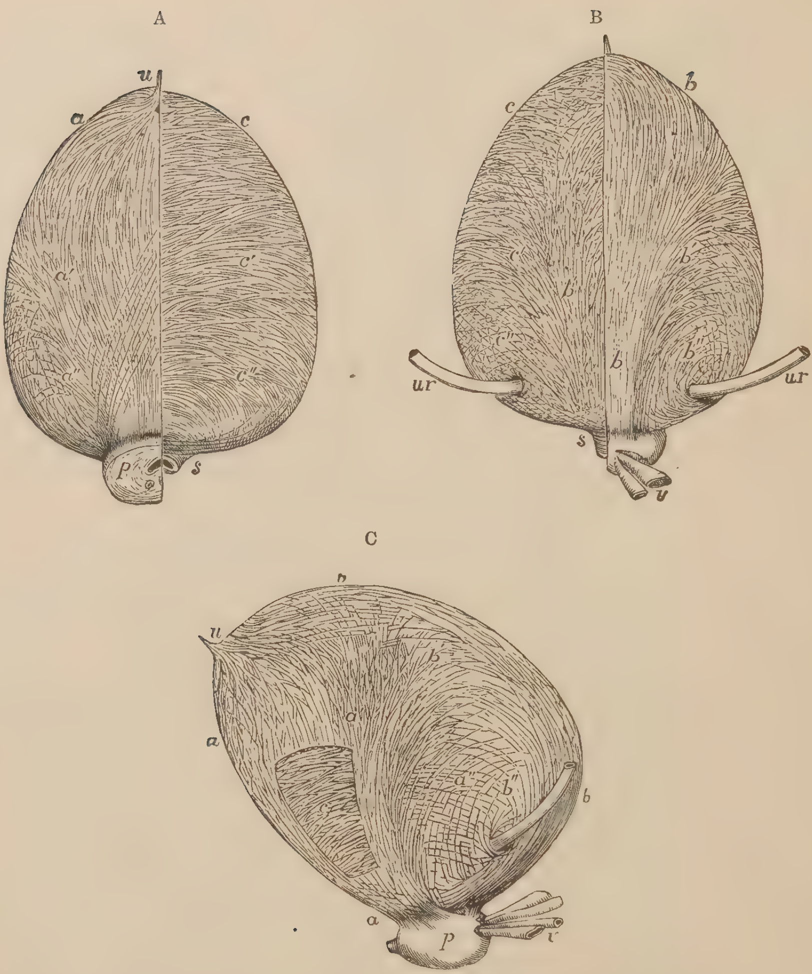


Fig. 216.—Dissections showing the course of the muscular fibres of the bladder. One-third natural size. (Allen Thomson, after Pettigrew, and from nature.)

A. From the front.

On the right side the superficial fibres are shown; on the left, the deep or circular fibres chiefly are displayed. *a*, on the right side, the median and most superficial bands of the longitudinal fibres, in which a slight decussation of fibres is seen; *a′*, those diverging somewhat; *a″*, the lowest, which pass much more obliquely; the attachment of the longitudinal fibres to the prostate is shown; on the left side, *c*, the upper, *c′*, the middle, *c″*, the lowest set of circular or deeper fibres; at *s*, the thickest and most transverse sets of these fibres forming the sphincter; *p*, right half of the prostate, the left half having been removed; *u*, the urachus, into which some of the longitudinal fibres are seen prolonged.

B. From the back.

On the right side the superficial fibres are displayed; on the left the deeper fibres of the same kind or intermediate fibres, and some of the circular fibres; *b*, *b*, the median, most superficial and strongest bands of longitudinal fibres on the right side; *b′*, the more diverging set of fibres near the middle of the bladder; *b″*, the most divergent fibres which surround the entrance of the ureters; on the left side, *c*, *c′*, and *c″*, indicate the deeper circular fibres passing round at various levels, and crossing with the deeper diverging fibres posteriorly; *s*, the most transverse fibres at the neck forming the sphincter; *u*, the urachus; *ur*, the ureters; the left half of the prostate has been removed to show the sphincter; *v*, part of the right ductus deferens and vesicula seminalis.

C. From the left side.

The anterior and posterior superficial fibres are seen running from below upwards, crossing each other by their divergence on the side of the bladder, and are indicated by the same letters as in the preceding figures; at *c*, a portion of the anterior longitudinal fibres has been removed so as to expose the deeper circular fibres.

the anterior and posterior surfaces of the bladder. Commencing in front at the neck of the organ, from the pubes in both sexes (*musculi pubo-vesicales*), and, in the male, from the adjoining part of the prostate gland, they may be traced upwards along the anterior surface to the summit of the bladder; and they may likewise be followed down over the posterior surface and base to the under-part of the neck of the bladder, where they become attached to the prostate in the male, and to the front of the vagina in the female. Upon the sides, the superficial fasciculi run more or less obliquely, and often intersect one another; in the male, they reach the prostate. At the summit, a few are continued along the urachus. The longitudinal fibres, taken together, constitute what has been named the *detrusor urinæ* muscle; but, according to Griffiths, these fibres 'do not form a separate muscle, and have not a separate function.'

The so-called *circular* fibres form a thin and somewhat irregular reticulated layer, distributed over the body of the bladder, having various directions in different bladders. Their course may in general be looked upon as transverse, but for the most part, throughout the upper two-thirds of the bladder, they cross one another in very oblique bands.

The *third stratum* of fibres, still more deeply situated, was first described by Ellis,[1] who distinguished it as 'submucous.' This layer is specially well developed at the base of the bladder. Beneath the trigone, it consists of a mass of fine transverse fibres, which are thickened posteriorly to form the ureteric bar, and are continuous in front with the sphincter vesicæ. A distinct layer of connective-tissue separates these transverse fibres from the longitudinal fibres beneath them. If the latter be cut across opposite the base of the trigone, this area of the bladder, with its submucous fibres and the ureteric openings, can readily be separated from the rest of the bladder.[2]

The muscular coat of the bladder forms so irregular a covering that, when the organ is much distended, intervals arise in which the walls are very thin; and, should the internal or mucous lining protrude in any spot through the muscular bundles, a sort of hernia is produced, which may go on increasing, so as to form what is called a vesical sacculus, or *appendix vesicæ*, the bladder thus affected being termed *sacculated*. Hypertrophy of the muscular fasciculi, which is liable to occur in stricture of the urethra, or other affections impeding the issue of the urine, gives rise to that condition named the *fasciculated* bladder, in which the interior of the organ is marked by strong reticulated ridges or columns, with intervening depressions.

Next to the muscular coat, between it and the mucous membrane—but much more intimately connected with the latter—is a well-marked layer of areolar tissue, the vascular or **submucous coat.** This submucous areolar layer contains a large number of finely coiled fibres of elastic tissue.

The **mucous membrane** of the bladder is soft, smooth, and of a pale rose colour. It is continuous above with the lining membrane of the ureters and kidneys, and below with that of the urethra. Neither here nor in the ureters is the mucous membrane provided with a muscularis mucosæ. It adheres loosely to the muscular tissue, and is thus liable to be thrown into wrinkles, except at the trigone, where it is always more even. It is covered with a (transitional) stratified epithelium similar to that of the ureters.

Blood-vessels, lymphatics, and nerves.—Arteries.—The *superior vesical* arteries proceed from the remaining pervious portions of the hypogastric arteries; in the adult, they appear as direct branches of the internal iliac. The *inferior vesical* arteries are usually derived from the anterior division of the hypogastric. In the female, the *uterine* arteries also send branches to the bladder.

[1] 'An Account of the Arrangement of the Muscular Substance in the Urinary and Generative Organs of the Human Body,' *Transactions of the Medico-chir. Society of London*, vol. xxxix., 1856.

[2] Wright and Benians, *op. cit.*, p. 229.

The neck and base of the organ appear to be the most vascular portions. The **veins** form large plexuses around the neck, sides, and base of the bladder; they eventually pass into the hypogastric veins.

The **lymphatics** form plexuses in the tunica muscularis and tunica adventitia, but appear to be absent in the tunica mucosa and tela submucosa. The lymphatics of the anterior wall of the bladder go to the anterior and lateral vesical glands; those from the posterior wall to the lateral vesical, iliac, and hypogastric glands.

Nerves.—The nervous supply of the bladder is bilateral, each half having its own nerves. On each side, the nerves are derived from two sources, namely: (*a*) from the *third*, the *fourth*, and sometimes the *second sacral nerves*: these fibres, which are known as the pelvic splanchnics (Gaskell), consist almost entirely of fine medullated nerves, and pass from the sacral spinal nerves directly to the pelvic plexus without going through the gangliated cord of the sympathetic. (*b*) From the *hypogastric plexus of the sympathetic*: these fibres are nearly all non-medullated. They arise from the upper lumbar nerves, and reach the hypogastric plexus through the aortic plexus and the inferior mesenteric ganglion. Both sets unite in the pelvic plexus, which contains numerous ganglia, and the fibres which go from the plexus to the bladder are mainly, if not entirely, non-medullated. According to von Zeissl, the pelvic splanchnics supply only the longitudinal fibres of the bladder; but Griffiths found that stimulation of the peripheral cut ends of these nerves produced contraction of the entire muscular coat on the same side. These nerves also contain sensory fibres from the bladder. Stimulation of the peripheral cut ends of the hypogastric fibres causes feeble contraction of the corresponding half of the bladder (Langley); and if the bladder be previously contracted, it causes rapid relaxation (Griffiths). The hypogastric plexus also contains sensory fibres, which probably reach the spinal cord through the *twelfth thoracic* and *first and second lumbar nerves.*

ORGANA GENITALIA.

The genital organs are grouped with the urinary, under the term **apparatus urogenitalis.** The reasons for this grouping have already been given (p. 204). The genital organs are divisible into male (**organa genitalia virilia**) and female (**organa genitalia muliebria**). In each sex these organs consist of a pair of glands, testes or ovaria, which are concerned in the formation of the sexual cells, spermatozoa or ova, and of the genital passages by which these cells are conveyed to the exterior. The conjugation of these two types of genital cells occurs in the female genital passages, and the product of their union is retained there for a considerable time in the earlier stages of development as the embryo, and in the later as the fetus while the male genital cells are discharged from the male passages as minute organisms. Hence arises a physiological necessity for a great increase in size of the female genital passages as compared with those of the male. In the earliest stages of their development, the genital organs of the two sexes are indistinguishable from one another: a pair of genital glands appear, which subsequently become testes or ovaria, while the genital ducts are at first identical. The formation of the genital passages is complicated by the fact that in both sexes two pairs of ducts are developed—Wolffian and Müllerian, the former becoming functional in the male and the latter in the female; and that the ducts which, in either sex, do not become functional, persist throughout life as rudimentary organs. While all the higher animals are commonly described as unisexual, it may be held that they are all potentially hermaphrodite: the characters of one sex being normally highly

developed, while those of the other remain latent or imperfectly developed. Anatomically, each sex possesses certain rudimentary organs of the opposite sex. Hermaphrodites are individuals who combine within themselves the essential characters of both sexes. Anatomical hermaphroditism may be divided into true or glandular (where both the testes and ovary are present), and false or tubal—the Müllerian ducts persisting in the male and the Wolffian in the female.

ORGANA GENITALIA VIRILIA.

Under this head will be included a description of a pair of glands—the testes—with their serous investments and other coverings; of a very long and complicated system of excretory ducts, with reservoirs for the storage of the semen, and of various structures closely related to the urethra—such as the prostate and bulbo-urethral glands, and certain masses of erectile tissue forming the penis.

THE TESTES AND THEIR ACCESSORY STRUCTURES.

The *testes* or *testicles*, the two glandular organs which produce the spermatozoa, are situated in the pouch of integument termed the *scrotum*, each being suspended by a funiculus spermaticus.

Funiculus spermaticus (*spermatic cord*).—The parts which form this cord are the excretory duct of the testis (named the ductus deferens), the spermatic artery and veins, lymphatics, nerves, and connecting areolar tissue. Besides this last, the cord has several coverings in common with the testis. The structures mentioned come together to form the cord at the abdominal inguinal ring, and, extending through the abdominal wall obliquely downwards and towards the middle line, escape at the subcutaneous inguinal ring, whence the cord descends over the front of the pubes into the scrotum to end at the back of the testicle. The spermatic cord is not formed until the testis begins to leave the abdomen, and it gradually increases in length during the descent of the testis.

Canalis inguinalis.—By the term inguinal canal is understood the space occupied by the spermatic cord as it passes through the abdominal wall. It extends from the subcutaneous to the abdominal inguinal ring, and is about 3·5 cm. in length. In the upper part of this course the funiculus has the fascia transversalis behind it, and is covered in front by the lower fibres of the internal oblique and transversalis muscles; lower down, it lies in front of the conjoined tendon of these muscles, the fibres of which have arched inwards over it, and its cremasteric covering is in contact anteriorly with the aponeurosis of the external oblique muscle. The inguinal canal is therefore said to be bounded posteriorly by the fascia transversalis above and the conjoined tendon below, and anteriorly by fibres of the transversalis and internal oblique muscles above, and the aponeurosis of the external oblique muscle below; while its floor is formed by the curving backwards of the inguinal ligament, and its roof by the apposition of the layers of the abdominal wall and the arched fibres of the internal oblique and transversalis muscles.

As it enters the inguinal canal, the funiculus receives a covering from the infundibuliform or internal spermatic fascia—a thin layer continuous with the fascia transversalis, and prolonged down from the margin of the abdominal ring; within the canal it receives a covering from the cremaster muscle and its layer of fascia; and, as it emerges from the canal, there is added superficially to this, the intercrural or external spermatic fascia prolonged from the margin of the subcutaneous ring.

The scrotum.—The scrotum forms a purse-like investment for the testes and the lower part of the spermatic cords. Its condition is liable to some variation

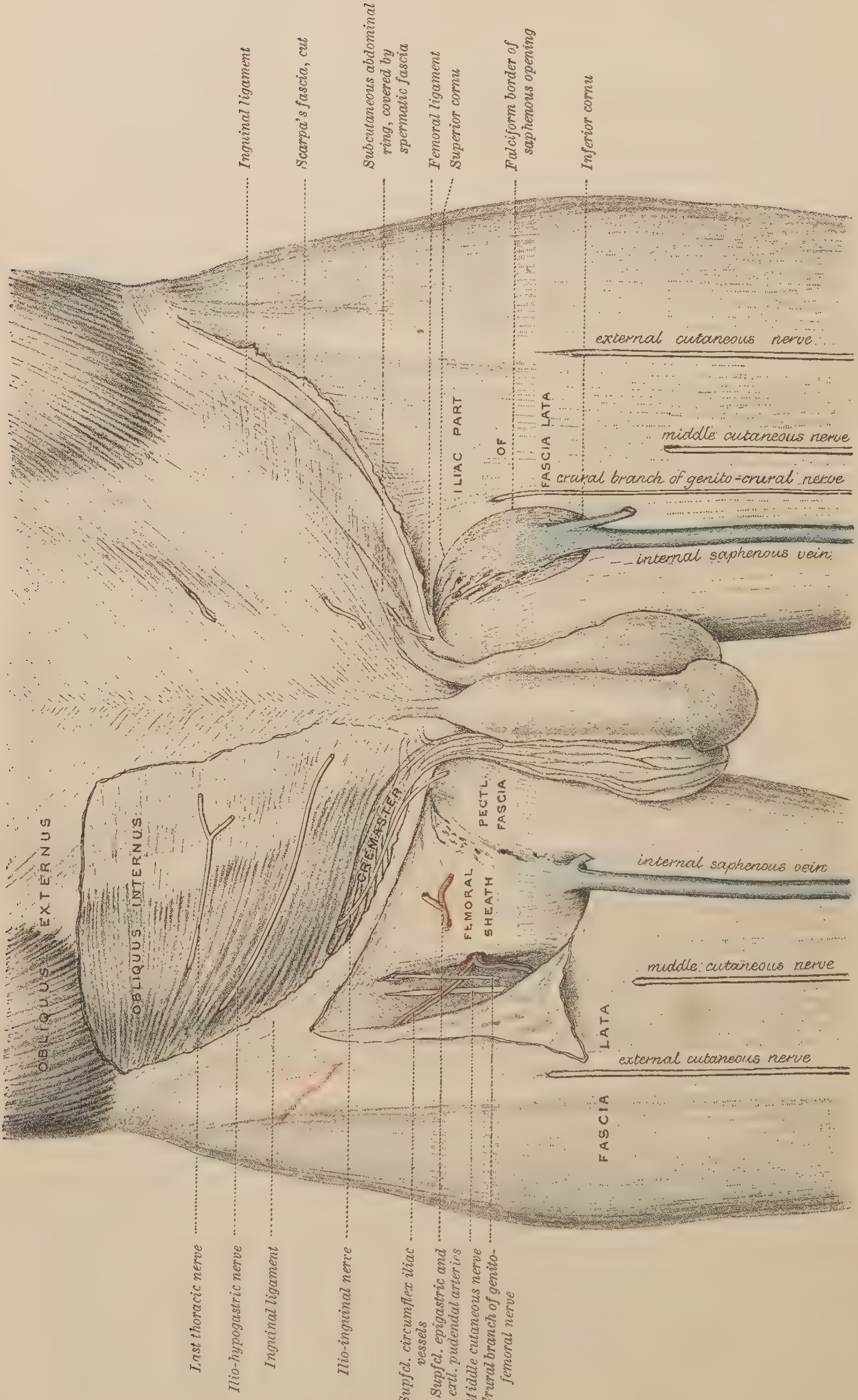


FIG. 217.—A SUPERFICIAL DISSECTION OF THE INGUINAL CANAL AND THE SPERMATIC CORD. (G. D. Thane.)

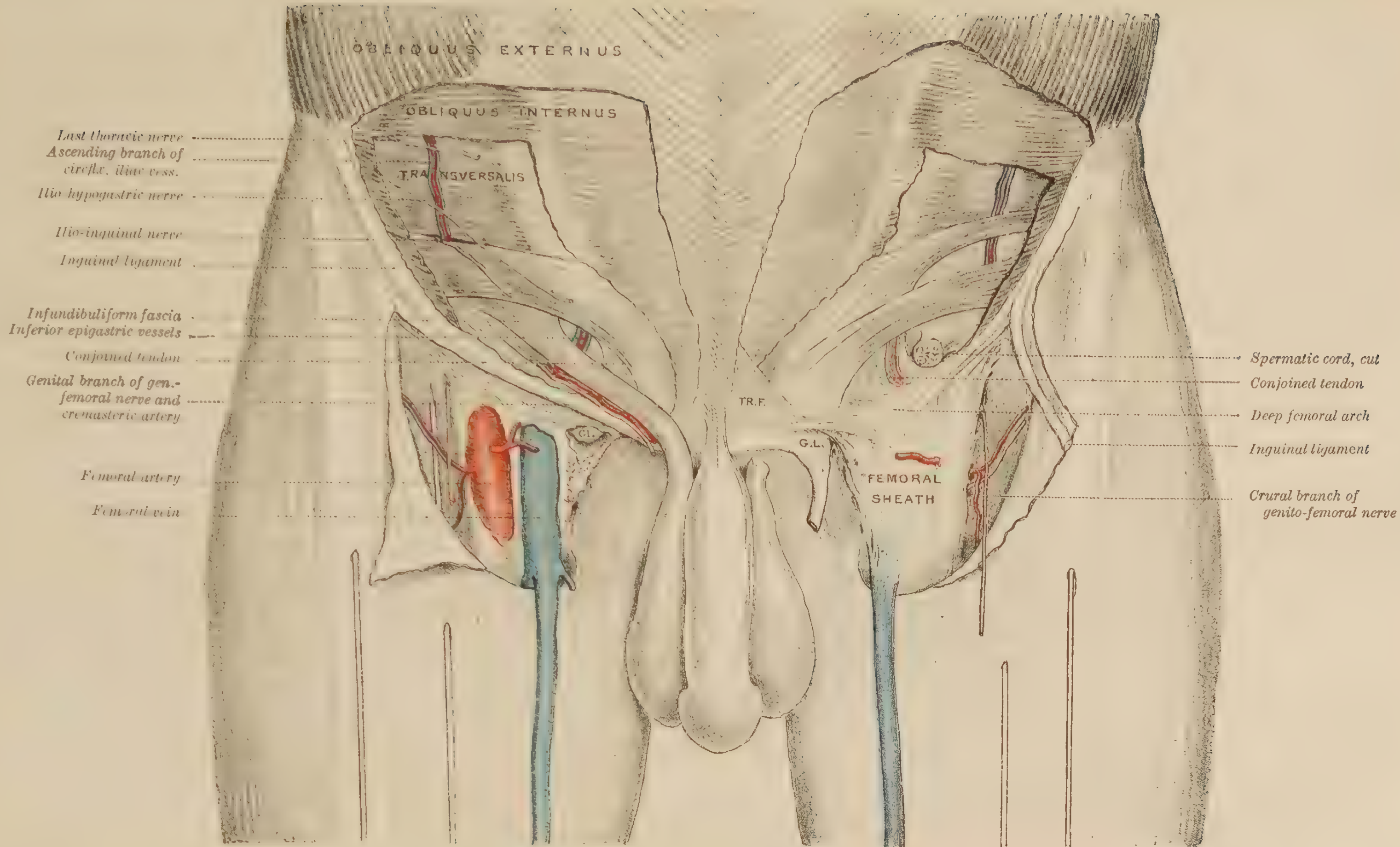


FIG. 218.—DEEP DISSECTIONS OF THE INGUINAL CANAL. (G. D. Thane.)

according to the state of the health and other circumstances : thus it is short and corrugated in robust persons and under the effects of cold, but becomes loose and pendulous in persons of weak constitution, and under the relaxing influence of heat. A superficial division into two lateral halves is marked by a slight median ridge, named the *raphe*, extending forwards to the under-side of the penis, and backwards along the perineum to the margin of the anus.

The coverings of the cord and testis in the scrotum may be enumerated from without inwards as follows: namely—the *skin* and the *dartos tissue*, the *intercrural*

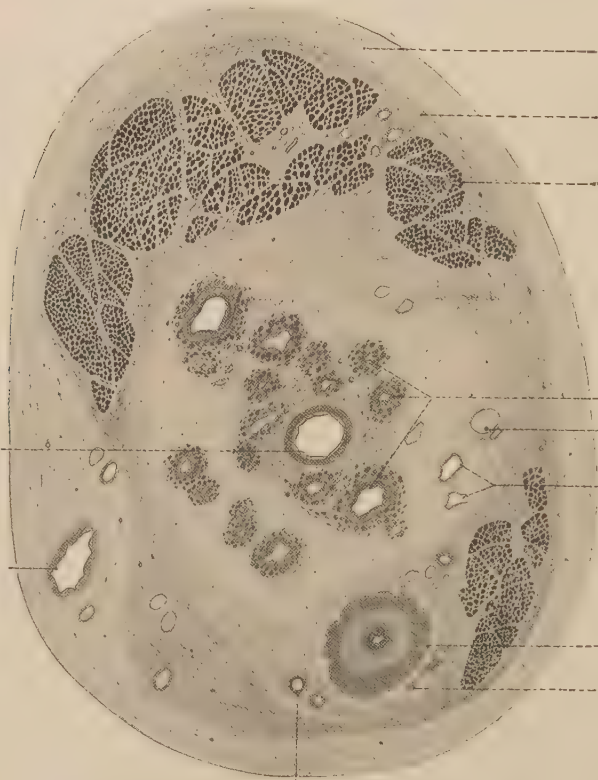


FIG. 219.—SECTION OF THE RIGHT SPERMATIC CORD OF A MAN, AGED TWENTY YEARS, AS SEEN FROM ABOVE. Magnified eleven diameters. (Eberth.)

fascia, the *cremaster muscle* and *fascia*, and the *infundibuliform fascia*, which is united to the cord by a layer of loose areolar tissue ; lastly, the special serous membrane of the testis, named the *tunica vaginalis*, which forms a closed sac, of which one part lines the scrotum and the other closely envelopes the testis.

1. The **skin** of the scrotum is very thin, and is of a darker colour than that of the body generally ; it is commonly thrown into rugæ or folds, which are more or less distinct, according to the circumstances already mentioned. It is furnished with sebaceous follicles, the secretion from which has a peculiar odour, and it is covered over with thinly scattered, curled and flattened hairs, the bulbs of which may be seen or felt through the skin when the scrotum is stretched. The superficial blood-vessels are also readily distinguished through this thin integument.

2. Immediately beneath the skin of the scrotum there is found a thin layer of a peculiar loose reddish-brown tissue, endowed with contractility, and named the

dartos tunic. This subcutaneous layer is continuous with the superficial fascia of the groin, perineum, and inner side of the thighs, but assumes a different structure, and is entirely free from fat. The dartoid tissue, which is more abundant on the fore part of the scrotum than behind, forms two distinct sacs for the corresponding testes, united together along the middle line so as to establish a median partition, named the *septum scroti*, which is adherent below to the deep surface of the raphe, and reaches upwards to the root of the penis. The dartos is very vascular, and owes its contractile properties to the presence of a considerable amount of unstriped muscular tissue (Kölliker).

3. The **intercrural** or **external spermatic fascia**—a very thin and transparent, but relatively firm, layer derived from the tendon of the external oblique muscle of the abdomen—is attached above to the margins of the subcutaneous ring, and is prolonged downwards upon the funiculus and testis. It lies at first beneath the superficial fascia and, lower down, beneath the dartos, and it is intimately connected with the layer next mentioned. It constitutes the *fascia cremasterica* of the 'B.N.A.'

4. The **cremasteric layer** is composed of scattered bundles of striped muscular fibres, connected together into a continuous covering by intermediate areolar tissue. The red muscular portion, which is continuous with the lower border of the internal oblique muscle of the abdomen, constitutes the *cremaster muscle*, and the entire covering is often named the *cremasteric fascia*. By the action of the cremaster, the funiculus is shortened and the testicle is raised towards the abdomen.

5. The **infundibuliform** or **internal spermatic fascia**, continuous above with the *fascia transversalis* and situated immediately beneath the cremasteric muscle, invests the funiculus completely, and is connected below with the posterior part of the testicle and the outer surface of its serous tunic. On forcing air beneath the infundibuliform fascia, a quantity of loose and delicate areolar tissue is seen to connect its deep surface with the ductus deferens and spermatic blood-vessels, and to form lamellæ between them. This areolar tissue is continuous above with the subserous areolar tissue found beneath the peritoneum on the anterior wall of the abdomen; below, it is lost upon the back of the testicle. Together with the infundibuliform fascia, it forms the *fascia propria* of Astley Cooper. The infundibuliform fascia is the *tunica vaginalis communis* of the 'B.N.A.' and must be distinguished from the *tunica vaginalis propria testis*, which is the serous sac of the testis derived from the peritoneum.

Lying amongst this loose areolar tissue, in front of the upper end of the funiculus, there is often seen a fibrous band, which is connected above with the pouch of peritoneum found opposite the upper end of the inguinal canal, and which passes downwards for a variable distance along the spermatic cord. Occasionally, it may be followed as a fine cord, as far as the upper end of the tunica vaginalis; sometimes no trace of it can be detected. It is the vestige of a tubular process of the peritoneum, which in the fetus connects the tunica vaginalis with the general peritoneal membrane. As fully described in Vol. I. (Embryology), the testis is developed in the abdomen in close relation to the Wolffian body, and subsequently lies near the kidney. During fetal life, it descends on the posterior abdominal wall from the lumbar region to the inguinal canal, which it traverses shortly before birth, and then passes down into the scrotum. At a period considerably prior to its escape from the abdominal cavity, a pouch of peritoneum already extends down into the scrotum. Into this pouch, or *processus vaginalis peritonæi*, the testicle projects from behind, supported by a duplicature of the serous membrane, named the *mesorchium*. Sooner or later, after the gland has descended into the scrotum, the upper part or neck of this pouch becomes contracted, and finally obliterated, from the abdominal ring down nearly to the testicle, leaving no trace but the indistinct fibrous cord already described, while the lower part remains as a closed serous sac surrounding the testicle, and which is hence named the tunica vaginalis testis.

In the female fetus, an analogous pouch of peritoneum descends for a short distance along

the round ligament of the uterus, and has received the appellation of the *canal of Nuck.* Of this, traces may almost always be seen in the adult.

The neck of the processus vaginalis sometimes becomes closed at intervals only, leaving a series of sacculi along the front of the cord; or a long pouch may continue open at the upper end, leading from the abdominal cavity into the inguinal canal. In other instances, the peritoneal process remains altogether pervious, and the cavity of the tunica vaginalis is thus made continuous with that of the peritoneum. In such a congenital defect, a portion of intestine or omentum may descend from the abdomen into the inguinal canal and scrotum, and constitute what is named a congenital hernia. Lastly, one or both testes may remain permanently within the abdomen, or their descent may be delayed till after puberty, when it may occasion serious disturbance. Retention of the testes in the abdomen (cryptorchismus) is, in many instances, the accompaniment of arrested development of the glandular structure; it is, however, a peculiarity which may be present without impotence. Rarely, a testis, after escaping from the inguinal canal, may pass to the front of the pubes above the penis, to the inner side of the thigh, or may descend at the side of the scrotum into the perineum. A few cases are recorded (see Romanovsky and Winiwarten, 'Dystopia testis transversa,' *Anat. Anzeig.*, Bd. xxvi., 1905) where both testicles descended on the same side.

In a few mammals, as the elephant, the testes remain permanently within the abdomen; in a much larger number, as the rodentia, they only descend at each period of heat. The complete closure of the tunica vaginalis is peculiar to man, and may be considered as connected with his adaptation to the erect posture.

6. The **tunica vaginalis.**—This tunic forms a closed sac, of which the opposite free surfaces are in contact with each other. Like the serous membranes in general, of which it presents one of the simplest forms, it may be described as consisting of a *visceral* and a *parietal* portion. The visceral portion (*lamina visceralis*) closely invests the greater part of the body of the testis, as well as the epididymis, between which parts it is depressed in the form of a pouch (*sinus epididymidis*) and lines their contiguous surfaces, and adheres intimately to the proper fibrous tunic of the gland. Along the posterior border of the gland, where the vessels and ducts enter or pass out, the serous coat, having been reflected, is wanting. This portion of the serous covering frequently presents villous prolongations on the borders of the epididymis and upper end of the testis; these processes, sometimes of considerable length, are covered in some places with cylindrical, in others with layers of flat, epithelium.

The parietal or scrotal portion of the tunica vaginalis is more extensive than that which covers the body of the testis; it reaches upwards, sometimes for a considerable distance, upon the spermatic funiculus, extending somewhat higher on the inner than on the outer side. It also reaches downwards below the testicle, which, therefore, appears to be suspended at the back of the serous sac, when this latter is distended with fluid; a fold, or so-called ligament, being left projecting at the lower end of the epididymis (fig. 220, *f*).

For a short period during the later months of fetal life, there is a *tunica vaginalis communis*, investing both the testis and the spermatic cord. After the obliteration of the portion covering the spermatic cord, the *tunica vaginalis propria testis* is left.

Blood-vessels, lymphatics, and nerves of the scrotum and spermatic cord.—The **arteries** are derived from several sources. The two *external pudendal* and the *anterior scrotal* arteries (branches of the femoral) reach the front and sides of the scrotum, supplying the integument and dartos; the *posterior scrotal* branches of the internal pudendal are distributed to the back part of the scrotum; lastly, more deeply seated than either of these, is a branch given from the inferior epigastric artery, named *cremasteric*, which is chiefly distributed to the cremaster muscle, but also supplies small branches to the other coverings of the cord, and by its ultimate divisions anastomoses with the other vessels. The *artery of the ductus deferens*, a long slender vessel derived from the superior or inferior

vesical, accompanies the tube in its whole length. The **veins** accompany the arteries. The veins of the cord form the spermatic or pampiniform plexus. The **lymphatics** of the scrotum form a close-meshed network, and the afferent vessels, five to eight in number, pass to the superficial inguinal glands—mainly the upper and median groups.

The **nerves** are derived from various sources. The *ilio-inguinal*, a branch of the lumbar plexus issuing by the subcutaneous ring, supplies the integuments of the scrotum; this nerve is joined also by a filament from the *ilio-hypogastric* branch of the same plexus: sometimes two separate cutaneous nerves come forward through the external ring. The two *posterior scrotal* branches of the pudendal nerve accompany the artery of the same name, and supply the inferior and posterior parts of the scrotum. The *perineal* branch of the posterior cutaneous of the thigh, joins with the posterior scrotal nerves, and with them is distributed to the sides and lower part of the scrotum. Lastly, the *genital branch of the genito-femoral* nerve, reaching the spermatic funiculus at the abdominal ring, passes with it through the inguinal canal, and supplies the fibres of the cremaster muscle, besides sending a few filaments to the other deep coverings of the cord and testicle. The ilio-inguinal and genito-femoral come from the first and second lumbar nerves, while the branches of the other nerves to the scrotum are derived from the third and fourth sacral nerves.

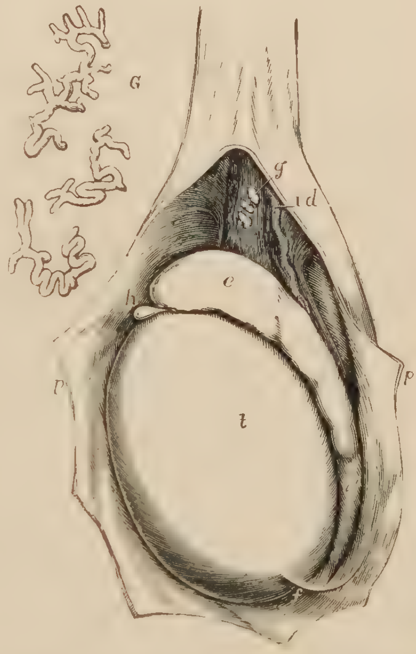


FIG. 220.—THE LEFT TUNICA VAGINALIS OPENED, SHOWING THE TESTIS, EPIDIDYMIS, ETC., FROM THE OUTER SIDE. (Allen Thomson.)

p, p, cut edges of the parietal layer of the tunica vaginalis drawn aside; *t*, body of the testis; *e, e'*, epididymis; *f*, a fold of the tunica vaginalis passing from the body of the testis to the side. In the upper part of the figure, the tunica vaginalis has been dissected off at the place of its reflexion on the cord to show *v d*, the ductus deferens, and *g*, the organ of Giraldès; *G*, the three small nodules of this organ enlarged about ten times, and showing the remains of tubular structure within them; *h*, appendix testis.

THE TESTES.

The **testes** (testicles), the principal reproductive glands in the male, two in number, are suspended obliquely in the scrotum by means of the cord and membranes already described; they are usually placed at unequal heights—that of the left side being lower than the other. They are of an ovoid form, but are slightly compressed from side to side, so that they have two somewhat flattened surfaces median and lateral—an upper and a lower end, an anterior and a posterior border. They are about 40 mm. long, 30 mm. wide from back to front, and 25 mm. thick from side to side. The weight of each varies from 15 grms. to 25 grms.

The front and sides of the testis, together with the upper and the lower ends, are free, smooth, and closely invested by the tunica vaginalis. The posterior border is attached to the spermatic cord, and it is here that the vessels and nerves enter or pass out. When the testis is suspended in its usual position, its upper end is directed obliquely forwards and outwards, as well as upwards, whilst the lower,

which is rather smaller, has the opposite direction. It follows from this that the posterior or attached border is turned upwards and inwards, and the outer flattened face slightly backwards.

Attached to the lateral part of the posterior border of the gland, is a long narrow body, the *epididymis*, which forms part of the excretory apparatus of the testicle, and is principally composed of the convolutions of a long tortuous canal or efferent duct, to be presently described. Its upper extremity, larger than the lower, projects forwards on the upper end of the testis, and is named the *caput epididymidis* or globus major (fig. 220, *e*) ; the lower, which is more pointed, is termed the *cauda* or globus minor ; whilst the intervening portion is named the *corpus*. The lateral convex surface of the epididymis is free and covered by the tunica vaginalis. The anterior concave surface is directed towards the testicle, to which it is attached at the caput and cauda ; but opposite the corpus it is free, and covered by the pouch of the tunica vaginalis, called the sinus epididymidis. The median rather ill-defined surface is related to the spermatic vessels. At its upper and lower extremity, the epididymis is attached to the testis by fibrous tissue (ligamentum epididymidis superius and ligamentum epididymidis inferius) and by a reflection of the tunica vaginalis. The globus major of the epididymis is also attached to the testicle by the efferent ducts of the testicle.

The **appendix testis** is a small structure, usually pedunculated, which is attached to the front of the upper pole of the testis, or sometimes to the groove between it and the caput epididymidis. It is often termed the hydatid of Morgagni ; but it is only in rare cases a sac containing fluid, being usually a soft reddish structure, composed of well-developed blood-vessels, &c., embedded in connective-tissue, and covered by columnar epithelium. On section, it is found to contain a minute duct, lined by columnar epithelium, which may end blindly or open into the cavity of the tunica vaginalis. It probably represents the remains of the cephalic end of the Müllerian duct (J. H. Watson, 'Some Observations on the Origin and Nature of the so-called Hydatids of Morgagni found in Men and Women, with special Reference to the Fate of the Müllerian Duct in the Epididymis,' *Jour. Anat. and Phys.*, vol. xxxvi., 1902).

Appendix epididymis.—This is a small pedunculated body attached to the front of the caput of the epididymis. The stalk may be a fine cylindrical thread about 10 mm. in length, but it is generally shorter. The appendix epididymis is less frequently present than the appendix testis. Toldt ('Die Anhangsgebilde des menschlichen Hodens und Nebenhodens,' *Sitz. d. k. Akad. d. Wissenschaften in Wien*, 1891) found it present in twenty-nine out of one hundred and five testes examined, and of the twenty-nine it was single in twenty-one, and in the remaining eight multiple ; in one of them there were as many as four appendices. It has essentially the same structure as the appendix testis (Wright and Brown, 'Anatomy of the Vestigial Structures in the Neighbourhood of the Epididymis,' *Brit. Med. Jour.*, vol. ii., 1912).

Variations in testes.—In addition to irregularities in position (which have already been referred to), the testes may vary in number. One testicle may be absent or very rudimentary. Various cases of supernumerary testicles have been reported (see Lowe, 'Double Testicle on One Side,' *Brit. Med. Jour.*, September 2, 1911 ; and Sparrow, 'Supernumerary Testicles,' *Ibid.*, September 20, 1911) as having been met with during an operation or in the physical examination of recruits ; but cases which do not permit of a microscopic examination of the accessory organ cannot be regarded as proved (see W. A. Sneath, 'An Apparent Third Testicle : consisting of a Scrotal Spleen,' *Jour. Anat. and Phys.*, vol. xlvi., April 1913).

STRUCTURE OF THE TESTIS AND EPIDIDYMIS.

The testis is enclosed in a strong capsule, the **tunica albuginea.** This is a dense unyielding fibrous membrane, of a white colour, and of considerable thickness, which immediately invests the soft substance of the testis, and preserves the form of the gland. It is composed of bundles of fibrous tissue, which interlace in every direction. The outer surface is covered by the tunica vaginalis, except along the posterior border of the testis, where the spermatic vessels pass through and the two extremities of the epididymis are attached.

In the interior, the fibrous tissue of the tunica albuginea is prolonged from the posterior border for a short distance into the substance of the gland, so as to form within it an incomplete vertical septum, known as the *corpus Highmori*, and named by Astley Cooper *mediastinum testis*. It extends from the upper nearly to the lower end of the gland, and it is wider above than below. The firm tissue of which it is composed is traversed by a network of seminal ducts, and by the larger blood-vessels of the gland, which are lodged in channels formed in the fibrous tissue.

From the front and sides of the mediastinum testis, numerous slender fibrous cords and imperfect septa of connective-tissue are given off in radiating directions,

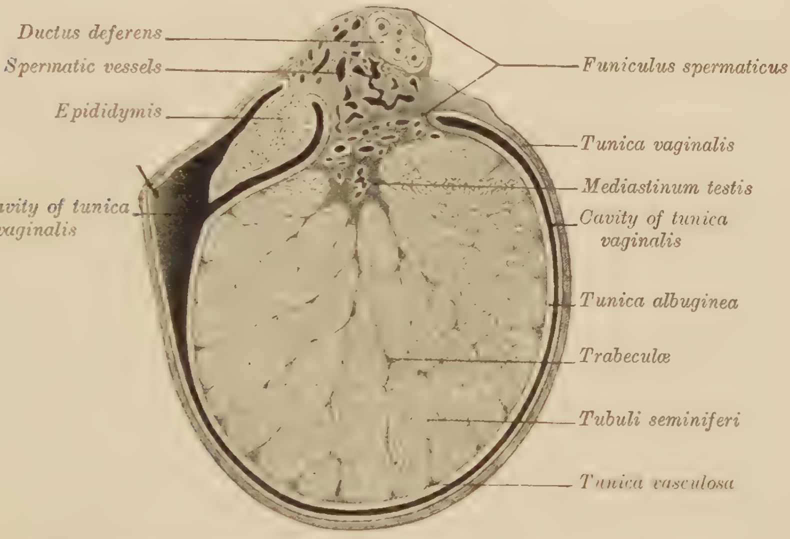


FIG. 221.—TRANSVERSE SECTION OF TESTIS, EPIDIDYMIS, AND SPERMATIC CORD. (Eberth.)

and are attached by their outer ends to the internal surface of the tunica albuginea at different points, thus incompletely dividing the glandular substance into lobules. According to Kölliker, plain muscular fibres are prolonged upon these septula. The whole internal surface of the tunica albuginea is covered by a multitude of fine blood-vessels, which are branches of the spermatic artery and veins, and are held together by a delicate areolar web. Similar delicate ramifications of vessels are seen on the various fibrous offsets of the mediastinum, upon which the blood-vessels are thus supported in the interior of the gland. This vascular network, together with its connecting areolar tissue, constitutes the *tunica vasculosa* of Astley Cooper.

The epididymis also possesses a tunica albuginea, but it is not so thick and firm as that of the testis.

At the back of the testis and epididymis, beneath the fascia propria and opposite the lower two-thirds of the testis, is a considerable amount of unstriped muscular tissue—the *inner muscular tunic* of Kölliker.

Seminiferous tubules.—The testis is a compound tubular gland in which the spermatozoa, or essential elements of the seminal fluid, are formed. The tubuli seminiferi occupy the fibrous framework formed by the albuginea, the mediastinum, and the trabeculæ, and they are loosely connected together by areolar tissue in the lobular spaces already described.

Of these lobules, there are some 100 to 200 (Krause), or more; they are of unequal size—the middle ones being the larger—and are imperfectly separated from one another, the septa being incomplete. In each lobule are two, three, or more seminiferous tubules closely convoluted (*tubuli seminiferi contorti*), and here and there branched—especially at their anterior or distal extremity—where, in a *cortical zone*, near the albuginea, they are stated frequently to communicate laterally with one another. It is not difficult to unravel the tubules for some distance, for their walls are moderately strong, and their diameter (0·2 mm.) large, compared with those of other tubular glands—such as the kidney. Their length is estimated to be on an average about 60 cm., and their number between 800 and 900, making a total of about 1,750 feet (Lauth). The structure of these tubules and the process of spermatogenesis is fully described in Vol. II., Pt. I.

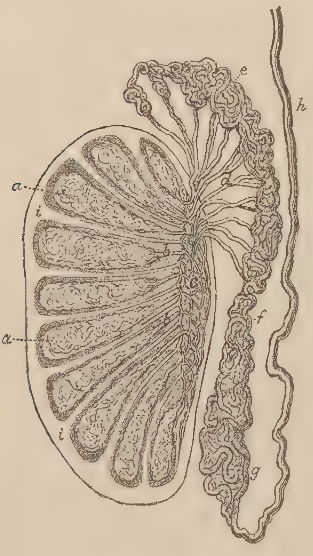


FIG. 222.—PLAN OF A VERTICAL SECTION OF THE TESTICLE, SHOWING THE ARRANGEMENT OF THE DUCTS.

The true length and diameter of the ducts have been disregarded. *a, a*, tubuli seminiferi contorti, coiled up in the separate lobes; *b*, tubuli seminiferi recti; *c*, rete testis; *d*, vasa efferentia ending in the coni vasculosi; *e, f, g*, convoluted canal of the epididymis; *h*, ductus deferens; *i, i*, section of the back part of the tunica albuginea with fibrous processes running between the lobes.

Ducts of the testis.—As the **tubuli seminiferi contorti** approach the mediastinum testis, they unite, as before said, with one another at acute angles into a smaller number of tubes, which have a less flexuous course, and at length become nearly straight. Close to the mediastinum, they taper into short, straight tubes (**tubuli seminiferi recti**), of smaller diameter than the seminiferous tubes (fig. 224), and differing from them in the character of their epithelium. This, in the straight tubules, is a single layer of flattened or cubical cells continuous with the outer or lining cells of the seminiferous tubes.

The straight tubules open into a network of channels which lies in the fore-part of the mediastinum, and is named **rete testis** (fig. 224, *c*). The tubes composing the rete have no proper walls, but are merely channels in the fibrous stroma, lined by flattened epithelium. Their diameter is greater than that of the tubuli recti. The secretion from the testis is accumulated in the rete testis, and is conducted to the upper and back part of the testis, whence it is conveyed away by the **ductuli efferentes testis**, or **vasa efferentia.** These are from twelve to fifteen, or sometimes twenty, in number; they perforate the tunica albuginea beneath the globus major of the epididymis—of which they may be said to form a part—and in the convoluted canal of which they ultimately terminate. On emerging from the testis, these vasa efferentia are straight, but, becoming more convoluted as they proceed towards the epididymis, they form a series of small conical masses, the bases of which are turned in the same direction, and are named *lobuli epididymidis*, or *coni vasculosi* (figs. 222, 225). They are about 0·5 mm. in diameter. The largest of the cones is about 14 mm. long, and when unrolled, each is found to consist of a single coiled duct, varying from 150 mm. to 200 mm. in length, and the diameter of which gradually decreases from the testis to the epididymis (Huschke). Opposite the globus major, these separate efferent vessels open at intervals—which, in the unravelled tube, are found to be about 75 mm. in length—into a single canal

or duct, the intervening and subsequent convolutions of which constitute the epididymis itself.

The **ductus epididymidis** (fig. 222, *e, f, g*) is disposed in very numerous coils, and extends from the globus major downwards to the globus minor or tail, where, turning upwards, it is continued on as the *ductus deferens.* When its complicated flexuosities are unrolled, it is found to be about 6 metres (twenty feet) in length. The smallest windings are supported and held together by fine areolar tissue; but besides this, numerous incomplete, transverse, fibrous partitions are interposed

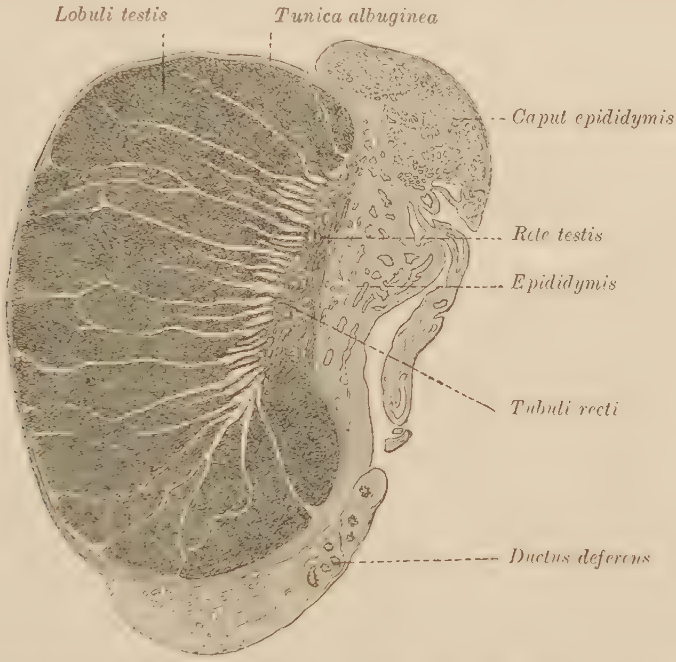


FIG. 223.—LONGITUDINAL SECTION THROUGH THE TESTIS AND EPIDIDYMIS. (Böhm and v. Davidoff.)

between larger masses of the coils. The canal of the epididymis is, at its commencement, about 0·4 mm. in diameter; but, diminishing as it proceeds towards the globus minor, is about 0·27 mm., after which it again increases in size, and becomes less convoluted as it approaches the ductus deferens. Its coats, which are at first thin, become thicker in its progress.

The vasa efferentia have a layer of circular muscular fibres, to which, in the tube of the epididymis, is added an external longitudinal layer, both being relatively thin. The epithelial lining-cells are columnar in form, and are ciliated—the cilia being long and causing by their movement a current towards the ductus deferens. In the epididymis the cells are greatly elongated; in the vasa efferentia, they are shorter; in the lower part of the epididymis the cilia disappear. Between the fixed ends of the columnar cells other smaller cells are met with.

The **ductus deferens** (*vas deferens*) (fig. 226, *h*) forms the continuation upwards of the convoluted duct of the epididymis, from which duct it is readily distinguished by its much larger size and the greater thickness and strength of its walls.

Course and relations.—It commences at the lower end of the epididymis, and, at first rather tortuous but afterwards becoming straight, it ascends upon the

median side of the epididymis, and along the back of the testicle, separated from both, however, by the blood-vessels passing to and from the gland. Continuing then to ascend in the spermatic cord, the ductus deferens accompanies the spermatic artery, veins, and nerves, as far as the upper end of the inguinal canal. Between the testicle and the lower end of the inguinal canal its course is nearly vertical: it lies behind the spermatic vessels, and is readily distinguished by its hard cord-like feel. It then passes obliquely upwards and outwards along the inguinal canal, and, reaching the median border of the abdominal inguinal ring, leaves the spermatic vessels (which extend to the lumbar region), and turns suddenly backwards and inwards round the lateral and posterior aspect of the inferior epigastric vessels to reach the

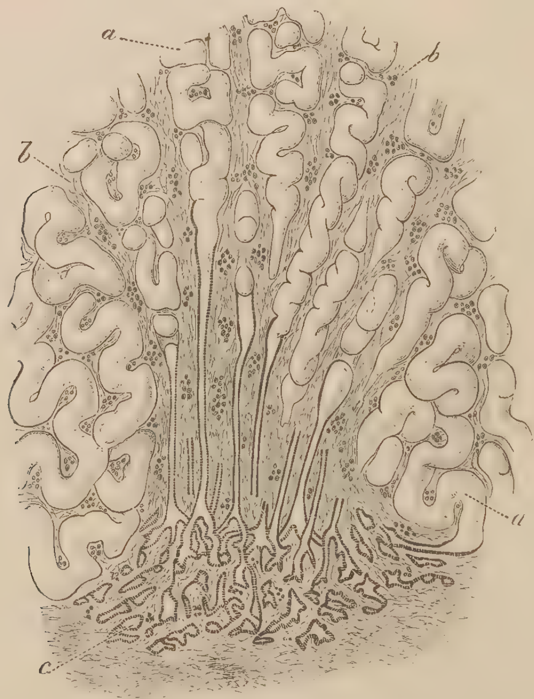


FIG. 224.—PASSAGE OF CONVOLUTED SEMINIFEROUS TUBULES INTO STRAIGHT TUBULES, AND OF THESE INTO THE RETE TESTIS. (Mihalkovics.)

a, convoluted seminiferous tubules, straight tubules not lettered; *b*, fibrous stroma continued from the mediastinum testis; *c*, rete testis.

side wall of the pelvis (fig. 227). From the abdominal ring, the ductus deferens passes nearly horizontally backwards for 8 cm. to 10 cm. in the direction of the ischial spine. In this part of its course, it lies just beneath the peritoneum and median to the external iliac vessels, the obturator vessels and nerve, and the ligamentum umbilicale laterale. It then comes into relation with the base of the bladder, and, leaving the peritoneum, curves downwards, median to the ureter. Upon the base of the bladder, the ductus deferentes lie between this organ and the rectum, and extend forwards and inwards between the vesiculæ seminales (fig. 230) until they reach the prostate, where each ductus deferens ends by joining with the duct from the corresponding seminal vesicle on its outer side to form one of the common seminal or ejaculatory ducts (fig. 230, E.D.).

As the ductus deferens lies on the side wall of the pelvis, it forms the posterior

boundary of the posterior paravesical fossa and the anterior boundary of the obturator fossa.[1] At the base of the bladder, it is enclosed with the seminal vesicle in a well-defined fibro-muscular sheath, and becomes dilated and somewhat tortuous, forming the *ampulla* of Henle.

Dimensions.—The ductus deferens measures 40 cm. to 45 cm. in length. In the greater part of its extent, it is cylindrical or slightly compressed, and has an average diameter of about 2·5 mm., with a lumen of 0·2 mm. to 0·5 mm.; but at the *ampulla* of Henle, which is about 3 cm. long, it may acquire a diameter

Fig. 225.—Ducts of the testicle injected with mercury. (From Haller.)

a, body of the testicle; *b*, tubuli in the interior of the gland; *c*, rete ducturi efferentes testis terminating in the coni vasculosi; *e*, *f*, *g*, convoluted canal of the epididymis; *h*, ductus deferens ascending from the globus minor of the epididymis.

Fig. 226.—Injected testis, epididymis, and ductus deferens. (From Kölliker, after Arnold.)

a, body of the testicle; *b*, lobules; *c*, vasa recta; *d*, rete testis; *e*, vasa efferentia; *f*, coni vasculosi; *g*, epididymis; *h*, ductus deferens; *i*, vas aberrans; *m*, branches of the spermatic artery passing to the testis and epididymis; *n*, ramification in the testis; *o*, artery of the ductus deferens; *p*, its union with a twig of the spermatic artery.

of about 7 mm. to 10 mm. Previously to its junction with the duct of that vesicle, it again becomes narrowed into a smaller and straight cylindrical canal.

Structure.—Besides an external areolar investment, and an internal mucous membrane, the ductus deferens is provided with an intermediate thick muscular tunic, of a deep yellowish colour. This coat consists of two layers of plain fibres: an outer of longitudinal and an inner of circular fibres (fig. 228, *d*, *e*). In addition, near the commencement of the tube, there is an internal longitudinal stratum, extremely thin, and constituting not more than one-fifth of the muscular coat (fig. 228, *c*); in the ampulla, the inner longitudinal fibres are absent.

The lining membrane exhibits on its surface three or four longitudinal ridges, and, besides this, in the sacculated portion of the duct, it is marked by numerous

[1] Waldeyer, 'Topographical Sketch of the Lateral Wall of the Pelvic Cavity, with Special Reference to the Ovarian Groove,' *Jour. Anat. and Phys.*, vol. xxxii., October 1897.

finer rugæ which enclose irregular polyhedral spaces, resembling in this alveolar character the lining membrane of the seminal vesicles, and is provided with simple and branched tubular glands (Henle) and well-marked diverticula. The epithelium is of the columnar kind, and non-ciliated. As in the epididymis, there is a deeper layer of small cells between the columnar cells.

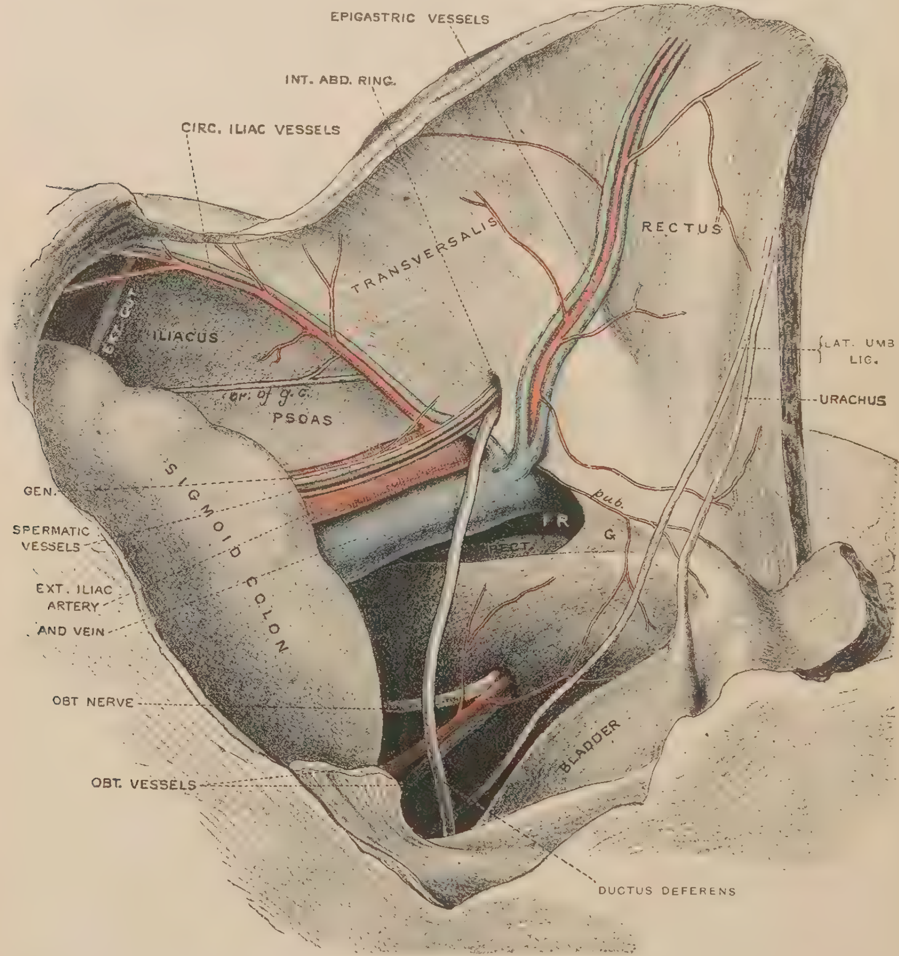


FIG. 227.—INNER VIEW OF THE GROIN, SHOWING THE DUCTUS DEFERENS PASSING FROM THE ABDOMINAL INGUINAL RING INTO THE PELVIS. (Ellis and Thane.)

The peritoneum and subperitoneal tissue have been removed; and the rectus and transversalis muscles are seen covered by the transversalis fascia. The ilio-psoas muscle and lateral cutaneous nerve are covered by the iliac fascia.

F R, femoral ring; G, ligamentum lacunare or Gimbernat's ligament; PECT., pectineus muscle covered by fascia; *pub.*, pubic branch of epigastric artery anastomosing with pubic of obturator.

The walls of the ductus deferens are very dense and strong, and feel hard to the touch, owing to the large proportion their thickness bears to the lumen of the tube. In the sacculated portion, the passage is much wider, and the walls are thinner in proportion.

Vas aberrans.—This name was applied by Haller to a long narrow tube, or diverticulum (ductus aberrans inferior) (fig. 226, *i*), discovered by him, and almost invariably met with, which leads off from the lower part of the canal of the epididymis, or from the commencement of the

ductus deferens, and, becoming tortuous and convoluted, is rolled up into an elongated mass, which extends upwards for 2 cm. to 3 cm. amongst the vessels of the spermatic cord, where the tube ends by a closed extremity. Its length, when it is unravelled, ranges from about 5 cm. to 30 cm., and its width increases towards its blind extremity. Sometimes this diverticulum is branched, and occasionally there are two or more such aberrant ducts. Its structure appears to be similar to that of the ductus deferens. Its presence is due to the persistence of one or more of the transverse tubules of the caudal part of the Wolffian body. Luschka states that occasionally it does not communicate with the canal of the epididymis, but appears to be a simple serous cyst.

Paradidymis (*organ of Giraldès*).—The small body thus named is situated in the front of the cord immediately above the caput epididymidis (see fig. 220, *g*). It consists usually of several small irregular masses containing convoluted tubules lined with columnar ciliated epithelium,

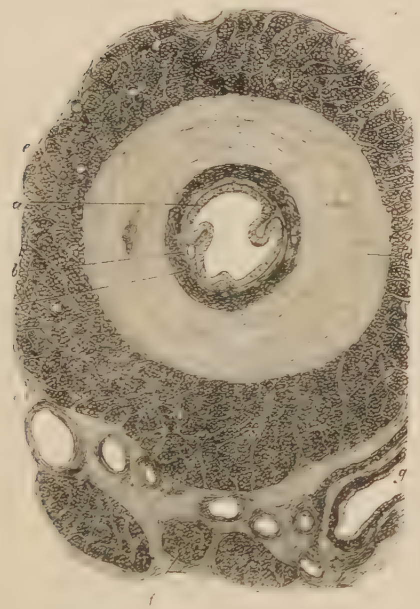


FIG. 228.—SECTION ACROSS THE COMMENCEMENT OF THE DUCTUS DEFERENS. (Klein.)

a, epithelium; *b*, mucous membrane; *c*, *d*, *e*, inner, middle, and outer layers of the muscular coat; *f*, bundles of the internal cremaster muscles; *g*, section of a blood-vessel.

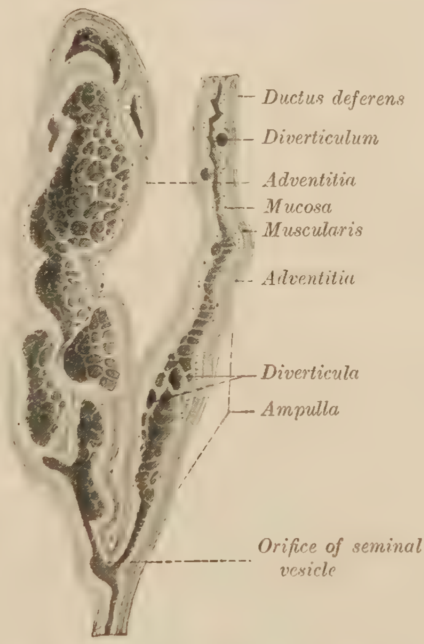


FIG. 229.—LEFT SEMINAL VESICLE WITH THE CORRESPONDING DUCTUS DEFERENS AND ITS AMPULLA. (Eberth.)

Coronal section. The interior looked at from behind.

and is scarcely to be recognised until the surrounding connective-tissue has been rendered transparent by re-agents. Toldt, 'Ueber die vasa aberrantia des Nebenhodens und über die Paradidymis.' (*Anat. Anzeig.*, Ergänzungsheft zum VII Jahrgang, 1892) distinguishes two of these organs: an upper, situated in front of the spermatic venous plexus and above the head of the epididymis; and a lower, having the same relation to the veins, but being behind the head of the epididymis. The upper body consists of a few small tubules, blind at each end, which are vestiges of the tubules of the Wolffian body. The tubules of the lower body may be closed at each side or may join by one extremity the body of the epididymis; they represent detached ductuli efferentes.

The **vesiculæ seminales** are two branched and sacculated diverticula of the ductus deferentes, situated one on each side between the bladder and the rectum. Each vesicle forms a somewhat oval mass with the narrow end in front and its long axis directed forwards, inwards, and downwards. The upper or anterior surface is somewhat flattened, and the lower or posterior convex. Their length is usually

about 5 cm., and the greatest breadth about 2 cm., and the thickness 1 cm.; but they vary both in size and shape in different individuals, and also on the two sides.

Their upper obtuse extremities are separated widely from each other (see fig. 231), but anteriorly they converge so as to approach the two ductus deferentes, which run forwards to the prostate between them. With the ductus deferentes thus interposed, they occupy the two diverging sides of the triangular portion of the base of the bladder, which lies upon the rectum, and is bounded behind by the line of reflexion of the peritoneum at the extremity of the recto-vesical pouch. With both bladder and rectum empty, only the anterior and inner part of each vesicle is in contact with these viscera, and the greater portion of the vesicle lies lateral to the recto-vesical pouch of peritoneum, and is separated below and at the side by fascia and a plexus of veins from the levator ani and obturator internus muscles (see fig. 231). As the bladder and rectum become distended, the intervening structures are pushed aside, and nearly the whole length of the vesicle is in contact with one or other of these viscera. Each vesicle is invested by a strong fibromuscular sheath.

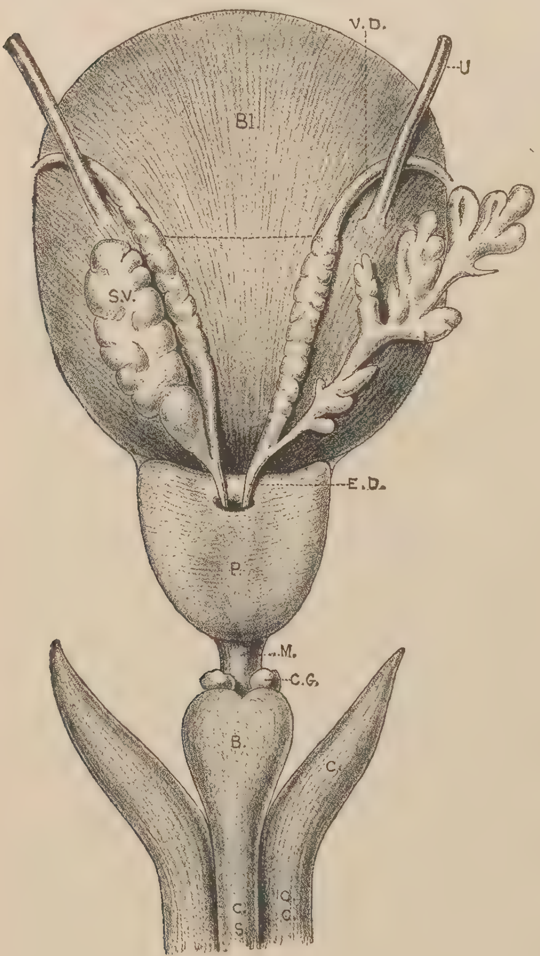


Fig. 230.—Diagram of the bladder, prostate gland, root of the penis, etc. (J. Symington.)

Bl, part of base of bladder covered by peritoneum, separated by a dotted line from a triangular space left uncovered by that membrane; U., ureter; S.V., seminal vesicle; E.D., ejaculatory duct; P., prostate; M., membranous part of the urethra; B, bulb; C.S., corpus cavernosum urethræ; C, crus penis; C.G., Cowper's gland.

The sacculated appearance of the seminal vesicles is owing to their peculiar formation. Each consists of a main duct more or less tortuous and having attached to it a variable number of blind diverticula which may be simple or branched. When unrolled, the main duct may be 10 cm., or more, in length, and about the same size as the ampulla of the ductus deferens. Occasionally, the posterior end of the vesicle is formed by a loop of the main duct and not by its blind extremity, which is curved forwards. Anteriorly, the main duct becomes straight and narrowed, and ends opposite the base of the prostate by uniting on its inner side, at an acute angle, with the narrow termination of the corresponding ductus deferens to form a single canal, which is the common seminal or ejaculatory duct.

Variations.—G. Pallin ('Beiträge zur Anatomie und Embryologie der Prostata und der Samenblasen,' *Arch. f. Anat.*, 1901), investigated the form and relations of the main duct and the diverticula in nineteen adult subjects, whose ages ranged from twenty-five to seventy-seven years, and found they varied considerably. He grouped his specimens under two main heads: (*a*) those in which the main duct was only slightly convoluted, and (*b*) those in which the convolutions were very tortuous. Under each head the diverticula were either short and fairly uniform in size, or very unequal; some being long and tortuous, and other branched.

Absence of the seminal vesicles is very rare. They are often unequal in size.

The seminal vesicles are considered by some authorities to serve as reservoirs for the testicular secretion; while others maintain that the material contained in the vesicles is secreted by their

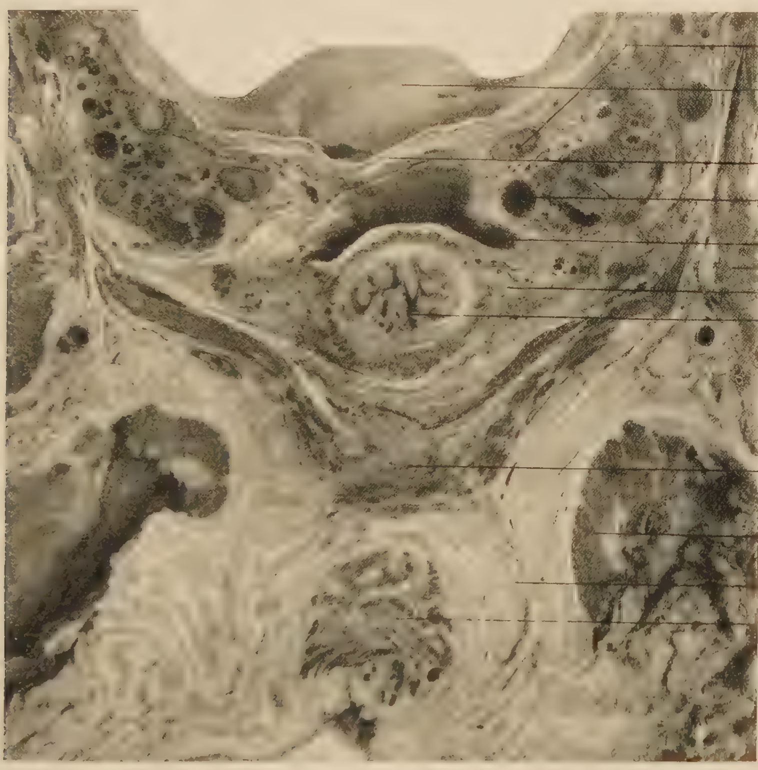


FIG. 231.—PHOTOGRAPH OF PART OF A CORONAL SECTION OF THE PELVIS OF A MAN, AGED FORTY YEARS, VIEWED FROM BEHIND. Natural size. (J. Symington.)

lining membrane, and becomes mixed with the semen in the act of ejaculation, the semen being stored in the epididymides and in the ampullæ of the ductus deferentes. W. Nagel (*Physiologie des Menschen*, Bd. ii., 1906) believes that their more important function is secretory. John Hunter showed that in the elephant, the ducts from the seminal vesicles open directly into the urethra, and consequently there are no ejaculatory ducts in this animal.

In structure, the seminal vesicles resemble very closely the adjoining sacculated portions of the ductus deferentes. Besides an external investment, connected with the recto-vesical fascia, and containing vessels of considerable size, lymphatics, and gangliated nerve-cords, they have a muscular coat and a mucous membrane. The muscular layers are thin compared with those of the ductus deferens, and consist of two layers: an outer of longitudinal and an inner of circular fibres. A considerable amount of plain muscular tissue is found covering the posterior surface and extending transversely between the two vesicles. There are also longitudinal fibres traceable over the vesicles from those of the bladder (Ellis, Henle). The mucous membrane is traversed by very many fine rugæ, which form an alveolar

structure resembling that seen in the gall-bladder, but deeper and enclosing much finer meshes. The epithelium of the vesicles is columnar with a deeper layer of small polyhedral cells.

The **ductus ejaculatorii**, or common seminal ducts, two in number, convey the semen into the urethra, and (fig. 242, E.D.) are formed on each side by the junction of the narrowed extremities of the corresponding ductus deferens and vesicula seminalis, close to the base of the prostate gland. From this point, they run forwards and downwards, at the same time approaching each other, and then pass side by side through the prostate between its middle and two lateral lobes. The duct of the seminal vesicle is in line with the ejaculatory duct, and the ductus deferens joins it at nearly a right angle.

After a course of about 16 mm., during which they become gradually narrower, they end in the floor of the prostatic portion of the urethra by two small slit-like orifices placed on the colliculus seminalis, one on each prominent margin of the opening of the prostatic utricle (fig. 242, *d*). For a short distance, the ejaculatory ducts run in the substance of the lateral walls of the utricle. At its origin, the ejaculatory duct is dilated to form the sinus ejaculatorius,[1] the lumen of which is about 0·8 mm., but the opening of the duct into the urethra is only about 0·2 mm. in diameter. Felix describes five recesses on the dorsal and median walls of the ejaculatory duct: the first and fourth, counting from below upwards, are purely diverticula, the remaining three are the ducts of glands.

Structure.—The mucous membrane is thrown into numerous folds, its epithelium contains yellow pigment, and the superficial cells are columnar. The duct proper has no muscular coat, except at the sinus, but the recesses have muscular walls.

Blood-vessels, lymphatics, and nerves of the testis and its ducts.—The blood-vessels, &c. of the testis differ from those of the scrotum, as they are carried down with the testis during its descent from the abdomen into the scrotum.

Arteries.—The *arteria testicularis* or *spermatic artery*, or proper artery of the testicle, is a slender and remarkably long branch, which arises from the abdominal aorta, and passing down the posterior abdominal wall, reaches the spermatic funiculus, and descends in it to the gland. In early fetal life, its course is much shorter, as the testis is then situated near the part of the aorta from which the artery arises. A little below the subcutaneous inguinal ring, the artery gives off a branch which supplies the coverings of the funiculus. The main trunk ends in two or more terminal branches, which, near the testicle, become tortuous and break up into numerous branches, some of which (capsular) ramify beneath the tunica albuginea and send twigs into the substance of the testis, while others (central) pass through the mediastinum and ramify along the septula testis before supplying the tubuli seminiferi. Near the upper end of the testis, small branches are given to the head of the epididymis, and others lower down supply the tail of the epididymis and anastomose with the artery on the ductus deferens.

The ductus deferens receives from one of the vesical arteries a long slender branch which accompanies the duct, and hence is named the arteria deferentia. It ramifies in the coats of the duct, and reaches as far as the testis, where it anastomoses with the spermatic artery.

Veins.—The *spermatic veins*, commencing in the testis and epididymis, pass out at the posterior border, where they unite into larger vessels, which freely communicate with each other as they ascend along the cord, and form the *pampiniform plexus*. Ultimately, two or three veins follow the course of the spermatic artery into the abdomen, where they unite into a single trunk (*spermatic vein*): that of the right side opening into the inferior vena cava, and that of the left into the left renal vein.

[1] W. Felix, 'Zur Anatomie des ductus ejaculatorius,' u.s.w. *Anat. Hefte*, Heft liv., 1901.

Lymphatics.—The lymphatic vessels accompany the spermatic blood-vessels, and, ascending with these in the spermatic cord and on the posterior abdominal wall, terminate in the lymphatic glands situated beside the abdominal aorta.

Nerves.—The nerves form a delicate set of sympathetic filaments, which arise from the renal and cœliac plexuses, and descend with the spermatic artery to the testicle. Some additional filaments, which are very minute, come from the hypogastric plexus and accompany the artery of the ductus deferens. The spinal fibres are derived from the tenth thoracic nerve.

PENIS.

The penis forms with the mons pubis and the scrotum the *partes genitales externæ*. It is composed mainly of cavernous tissue, and serves, when distended with blood, as the male organ of copulation. The cavernous tissue is arranged in three long and somewhat cylindrical masses, which are enclosed in fibrous sheaths, and are united together in a part of their course so as to form a three-sided prism which, surrounded by the general integument, constitutes the body of the penis. Of these masses, two, named *corpora cavernosa penis*, placed side by side, form the principal part of the organ, whilst the other, situated beneath the two preceding, surrounds the canal of the penile portion of the urethra, and is named *corpus cavernosum urethræ* or *corpus spongiosum*.

The skin which encircles the body of the penis is prolonged from the so-called dorsum of the penis upwards over the pad of fat forming the mons pubis, while on the under-surface the integument is folded to form the scrotum (see fig. 232).

Behind the bend in the flaccid penis, the three masses of cavernous tissue extend backwards and somewhat downwards into the perineum as the root of the penis. The penis is attached at its root to the symphysis of the pubes, and to the pubic arch ; in front, it ends in an enlargement named the *glans*, which is structurally similar to and continuous with the corpus cavernosum urethræ.

The *glans penis*, which is slightly compressed above and below, has at its extremity a vertical fissure forming the external orifice of the urethra (*orificium urethræ externum*) ; its base, which is wider than the body of the penis, is hollowed out to receive the narrowing extremities of the corpora cavernosa ; its border is rounded and projecting, and is named the *corona glandis*, behind which is a constriction of the penis named the *collum glandis*.

The skin of the body of the penis, which is continued from that of the pubes and scrotum, forms a simple investment as far as the neck of the glans. Here it projects forwards, then turns inwards and backwards over the glans, forming a loose fold consisting of a superficial and a deep layer of the integument. This fold is the *præputium* or fore-skin. The free anterior border of the prepuce forms a ring (the *annulus præputialis maris*) which bounds the *orificium præputii* ; while the space between the prepuce and the glans is sometimes called the balano-preputial. The inner layer of the prepuce is firmly attached behind the cervix ; and from thence the integument, becoming closely adherent, is continued forwards over the corona and glans, as far as the orifice of the urethra, where it meets with the mucous membrane of the urethra. The line of attachment of the prepuce is directed from the dorsum obliquely, downwards and forwards, round the sides to the under-aspect of the penis, where the two lateral folds of the prepuce unite, and are prolonged forwards as a small median fold (the *frenulum præputii*) to within a short distance of the orifice of the urethra. The groove between the attachment of the prepuce and the corona glandis is known as the sulcus retroglandis or collum glandis. On each side of the frenulum, this groove deepens to form the fossa frenuli.

Upon the body of the penis the skin is thin, free from fat, and, in the anterior two-thirds of its length, from hairs also : in these respects differing remarkably from that on the pubes, which is thick, covers a large cushion of fat, and, after puberty,

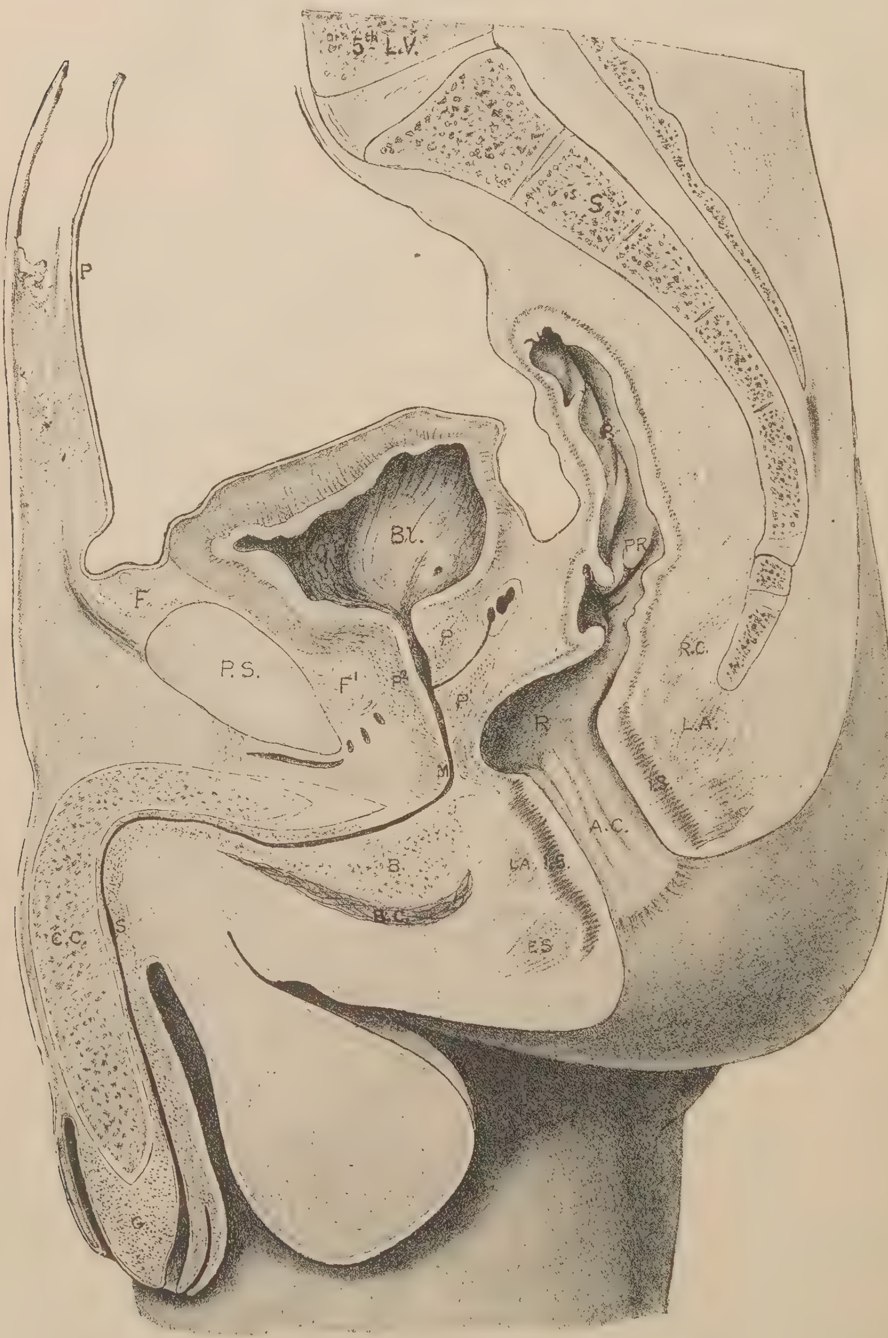


FIG. 232.—MEDIAN SECTION OF MALE PELVIS, PENIS, AND SCROTUM. Three-fifths natural size. (J. Symington.)

C.C., corpus cavernosum ; S, corpus cavernosum urethræ ; B, its bulb ; G, part forming the glans penis. For the other lettering, see fig. 118.

is beset with hairs. The skin of the penis is, moreover, very movable and distensible, and is of a darker colour than the skin generally. At the free margin of the prepuce, the integument changes its character, and approaches that of a mucous membrane, being red, thin, and moist.

Upon the surface of the glans, the integument is firmly and intimately adherent to the cavernous tissue of the glans, and presents a bluish-red appearance, due to the colour of the blood shining through the thin skin. The surface of the glans is usually smooth, but occasionally possesses papillary elevations.

The *smegma præputii*, or white creamy material, which tends to collect between the prepuce and the posterior part of the glans, is derived from the desquamation of the epithelial cells in this region—few if any glands being found there.

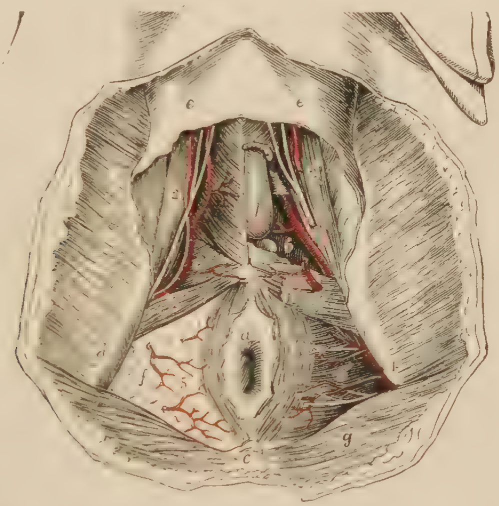


Fig. 233.—Dissection of the perineum in the male. Half natural size. (Allen Thomson.)
The right side shows a superficial, the left a deeper, view.

a, anus, with a part of the integument surrounding it; *b*, left half of the bulb of the corpus cavernosum urethræ, exposed by the removal of the bulbo-cavernosus muscle; *c*, coccyx; *d*, right ischial tuberosity; *e*, *e*, superficial perineal fascia; *f*, fat occupying the right ischio-rectal fossa; *g*, gluteus maximus muscle; 1, on the right transverse perineal muscle, behind the superficial perineal artery as it emerges in front of the muscle; 1′, on the left side, on the surface of the inferior fascia and the urogenital diaphragm behind the superficial perineal artery cut short; 2, on the right ischio-cavernosus muscle, lateral to the superficial perineal artery and nerves passing forwards; 2′, on the left side, the same vessel and nerves divided; 3, the right half of the inferior fascia; 4, left ischial tuberosity, lateral to the pudendal artery deep in the ischio-rectal fossa; 5, 5′, inferior hæmorrhoidal branches of the pudendal arteries and nerves; 6, on the left side, placed in a recess from which the inferior fascia has been removed, in order to show the continuation of the pudendal artery, its branch to the bulb, and Cowper's gland.

Beneath the skin, on the body of the penis, the superficial fascia is very distinct; it is continuous with that of the groin, and also with the dartos tissue of the scrotum, and resembles the dartos in containing non-striped muscular fibres, which are mainly circular in direction.

Ligamenta penis.—Under this term may be included two layers of fascia: a superficial (*ligamentum fundiforme penis*), and a deep (*ligamentum suspensorium penis*). The *ligamentum fundiforme* arises in the abdomen from the linea alba and the adjacent portion of the aponeurosis of the external oblique muscle, 4 cm. to 5 cm. above the symphysis pubis, and extends downwards as a broad band of elastic fibres towards the dorsum of the penis, near which it divides into two lateral bundles, which pass one on each side of the penis, and are then continued downwards into the

septum of the scrotum. The *ligamentum suspensorium* lies behind the fundiform ligament, and is much smaller: it is triangular in form, its anterior border is free, its upper border is connected with the fore part of the pubic symphysis, and below it runs down upon the dorsum of the penis, and blends with the tunicæ albugineæ of the corpora cavernosa penis.

The integuments of the penis are supplied with blood by branches of the *dorsal artery of the penis* and *external pudendal artery*; the veins join the *dorsal* and *external pudendal* veins. Their nerves are derived from the *dorsal* branches of the *pudendal nerves* and from the *ileo-inguinal*. The lymphatics arise in the prepuce and the integument of the glans, and, passing backwards, are joined by vessels from the skin of the body of the penis. They unite to form several trunks, which lie on the dorsum of the penis, and then turn outwards to end in the superficial inguinal glands.

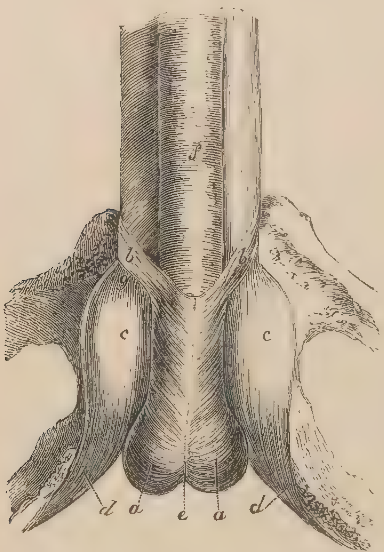


FIG. 234.—ROOT OF THE PENIS ATTACHED TO THE RAMI OF THE PUBES AND ISCHIUM. Two-thirds natural size. (Kobelt.)

a, *a*, bulbo-cavernosus muscle covering the bulb of the urethra, with at *e*, posteriorly, a median notch; *b*, *b*, anterior slips of the bulbo-cavernosus muscle passing round the sides of the corpora cavernosa penis; *c*, *c*, crura of the penis, with an oval dilatation of bulb of the corpus cavernosum penis; *d*, *d*, ischio-cavernosi or erectores penis muscles; *f*, corpus cavernosum urethræ.

The **corpora cavernosa penis** form the principal part of this organ. They are two cylindrical bodies placed side by side, flattened on their median aspects, and closely united and in part blended together along the middle line in the anterior three-fourths of their length; whilst at the back part, below the symphysis pubis, they separate from each other in the form of two bulging and then tapering processes, named *crura*, which, extending backwards, are attached to the pubic and ischial rami, and are invested by the erectores penis or ischio-cavernosi muscles. The enlarged portions at the root, named by Kobelt the *bulbs of the corpora cavernosa*, attain a much greater proportionate development in some quadrupeds than in man. In front, the corpora cavernosa are closely bound together into a blunt conical extremity, which is covered by the glans penis and firmly connected to its base by fibrous tissue.

The under-surface of the united cavernous bodies is marked by a longitudinal groove, in which is lodged the corpus cavernosum urethræ. The upper or anterior surface is also marked with a slight median groove in which the dorsal vein of the penis is situated, and near the root is attached to the pubes by the suspensory ligament.

Structure.—The median septum (**septum penis**) between the two corpora cavernosa is thick and complete near the root of the penis; but farther forward it becomes thinner, and only imperfectly separates their cavities; for it exhibits—particularly towards the anterior extremity—numerous clefts, extending from the dorsal to the urethral edge, and admitting of a free communication between the erectile tissue of the two sides. From the direction of these slits, the intermediate white portions of the septum resemble somewhat the teeth of a comb, and hence the partition has received the name of *septum pectiniforme*.

The **tunica albuginea**—the external fibrous investment of the cavernous structure—is white and dense, from one to two millimetres thick, and very strong and elastic. It is composed for the most part of longitudinal bundles of shining white fibres, with numerous well-developed elastic fibres, enclosing the two corpora cavernosa in a common covering; and internal to this, each corpus cavernosum is surrounded by a layer of circular fibres, which enter into the formation of the septum.

From the interior of the fibrous envelope, and from the sides of the septum, numerous lamellæ, bands, and cords—composed of fibrous, elastic and plain muscular tissue, and named *trabeculæ*—pass inwards, and run through and across the cavity in all directions, thus subdividing it into a multitude of interstices, and giving the entire structure a spongy character.

The trabeculæ, whether lamelliform or cord-like, are larger and stronger near the circumference than along the centre of each cavernous body, and they also become gradually thicker towards the crura. The interspaces, conversely, are larger in the middle than near the surface; their long diameter is, in the latter situation, placed transversely to that of the penis, and they become larger towards the fore-part of the penis. They are occupied by venous blood, being in reality large cavernous veins, and are lined by a layer of flattened epithelium similar to that lining other veins.

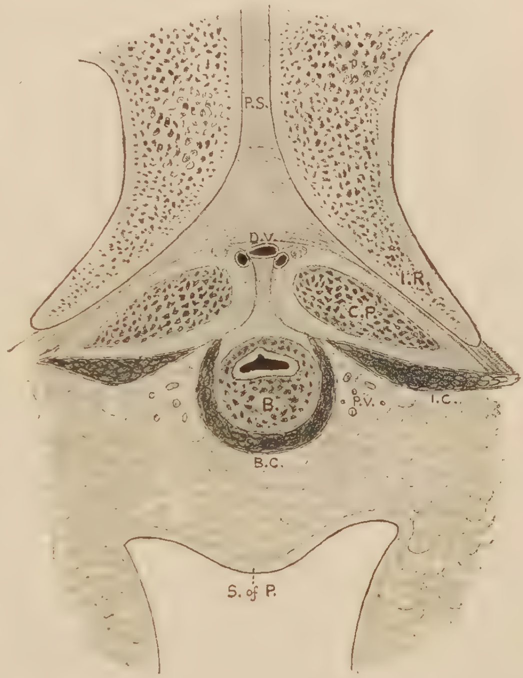


Fig. 235.—Transverse section passing from above downwards and backwards through pubic symphysis, root of penis, and skin of perineum. Natural size. (J. Symington.)

P.S., pubic symphysis; I.R., inferior ramus of pubis (the ramus of the ischium and the ischial tuberosity are posterior to the plane of this section); C.P., crus penis; B., bulb of corpus cavernosum urethræ; I.C., ischio-cavernosus muscle; B.C., bulbo-cavernosus muscle; P.V., superficial perineal vessels and nerves; S. of P., skin of perineum; D.V., dorsal vein of penis with an artery and a nerve on each side.

The intertrabecular spaces thus form a labyrinth of intercommunicating venous areolæ, divided by the trabecular tissue, and opening freely from one corpus cavernosum to the other through the septum, especially in front. The blood is carried away from these spaces by the dorsal vein, which ends in the prostatic plexus, and the profunda veins, which are tributaries of the hypogastric veins. The arteries of the corpora cavernosa are the two terminal branches of the internal pudendals: namely, the dorsal and profunda branches of the penis, which pierce the tunica albuginea to reach the cavernous tissue. Within this tissue, the numerous branches of arteries are supported by the trabeculæ, in the middle of which they run, and terminate in branches of capillary minuteness, which open into the intertrabecular spaces; some of the arterial twigs project into the spaces and form peculiar curling and somewhat dilated vessels, which were named by J. Müller, *helicine arteries*.

These are usually bound down by small fibrous bands, and it appears to be due to this circumstance that these projecting vessels acquire a looped or tortuous aspect when distended with injection.

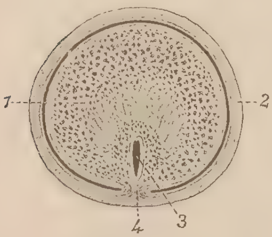


Fig. 236.

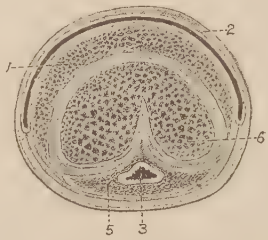


Fig. 237.

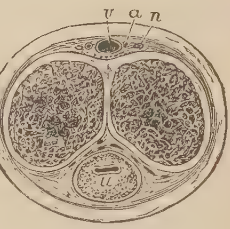


Fig. 238.

Fig. 236.—Transverse section of the glans penis in a distended state, 12 mm. behind the meatus. (J. Symington.)

1, glans penis; 2, prepuce; 3, urethra; 4, frænum of the prepuce.

Fig. 237.—Transverse section of the glans penis in a distended state, 20 mm. behind the meatus. (J. Symington.)

1, glans penis; 2, prepuce; 3, urethra; 5, corpus cavernosum urethræ; 6, corpus cavernosum penis.

Fig. 238.—Transverse section of the body of the penis in the distended state. (Altered from Henle.)

The outer outline indicates the integument surrounding the deeper parts; the erectile tissues of the corpora cavernosa and the septum pectiniforme are shown in section; *u*, placed on the section of the spongy body, below the urethra; *v*, the single dorsal vein; *a*, the dorsal artery, and *n*, the nerve of one side.

The helicine arteries are most abundant in the posterior part of the corpora cavernosa penis, and are found in the corresponding part of the corpus cavernosum urethræ also; but they have not been seen in the glans penis. They are more

Fig. 239.—Section of erectile tissue of penis in a non-distended condition. (Cadiat.)

a, trabeculæ of connective tissue with many elastic fibres and bundles of plain muscular tissue cut across (*c*); *b*, venous spaces.

distinct in the human subject than in animals, where they are often absent. Small capillary branches pass from them to supply the tissue of the enclosing sheath.

In addition to the blood which passes into the venous spaces from the capillary

network of the sheath and trabeculæ, some small arteries are said by C. Langer to open directly into the larger venous spaces.

Many of the small arteries present localised thickenings of the tunica intima (Intimapolster of Eberth), which by contraction of the circular muscular fibres can obliterate the lumen of the vessels.

The **corpus cavernosum urethræ** is usually described as surrounding the whole of the penile portion of the urethra, and presenting a posterior and an anterior dilatation known respectively as the *bulbus urethræ* and the *glans penis*. The bulb lies below the fascia diaphragmatis urogenitalis inferior, where it is placed between the diverging crura of the corpora cavernosa penis. Its free, rounded posterior extremity reaches backwards beyond the urethra to within about 2 cm. of the lumen of the anal canal, and the bulb also bulges downwards below the urethra towards the skin of the perineum. The size of the bulb varies according to the amount of blood in its cavernous spaces; but, on an average, it has a transverse diameter of 2·5 cm. and a vertical of 2 cm. (see fig. 243). Its length cannot accurately be determined because it gradually diminishes in size as it passes forwards, but it does not gain the ordinary dimensions of its middle part until about 3 cm. from its posterior free end.

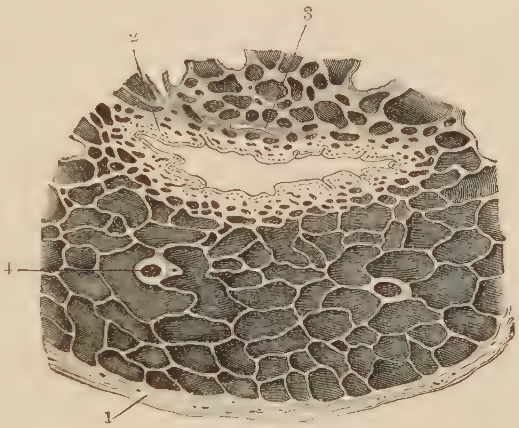


Fig. 240.—Section of the corpus cavernosum urethræ injected from its artery. (Henle.)

1, fibrous tunic of the corpus cavernosum urethræ; 2, mucous membrane of the urethra; 3, section of a lacuna of the mucous membrane; 4, section of an artery.

It receives a thin investment from the fascia on which it rests, and is embraced by the ejaculator urinæ, or bulbo-cavernosus muscle. The posterior extremity of the bulb exhibits, more or less distinctly, a subdivision into two lateral portions or lobes, separated by a slight furrow on the lower surface, and by a slender fibrous partition within, which extends for a short distance forwards; in early infancy this is more marked. It is above this part that the urethra, having pierced the inferior fascia, enters the bulb, surrounded obliquely by a portion of the cavernous tissue, named by Kobelt the *colliculus bulbi*: from which a layer of venous erectile tissue passes back upon the membranous and prostatic portions of the urethra to the neck of the bladder, lying closely beneath the mucous membrane. At first, the urethra is nearer the upper than the lower part of its corpus cavernosum, but it gradually gains, and continues to occupy, the middle of that body.

The part of the corpus cavernosum urethræ, which lies between the bulb and the glans, forms a fairly uniform cylindrical investment for the urethra, and has a diameter of about 10 mm.

The glans penis forms a conical mass with an anterior blunt apex and a concave base, which fits like a cap over the anterior extremities of the corpora cavernosa penis.

From the researches of Ritterer ('Sur le dévéloppement du penis et du clitoris chez les fœtus humains,' *Jour. de l'Anat. et de la Phys.*, 1892), Forster ('Beiträge zur Anatomie der äusseren

männlichen Geschlechtsorgane des Menschen,' *Zeit. f. Morph.*, Bd. vi., 1903), and Lichtenberg ('Beiträge zur Histologie, mikroskopischen Anatomie und Entwickelungsgeschichte des Urogenitalkanals des Menschen und seiner Drüsen,' *Anat. Hefte*, Heft 93, 1906) there appear to be good reasons for describing the cavernous tissue of the glans as the *corpus cavernosum glandis* rather than as a part of the *corpus cavernosum urethræ.* It is developed as an independent structure, and its cavernous tissue becomes connected with that of the corpus cavernosum urethræ by dilated veins and not by direct continuity of cavernous tissue.

Structure.—This is essentially the same as that of the corpora cavernosa penis, but with a much less developed fibrous framework. Like the penile portion, it is distended with blood during erection, but it never acquires the same rigidity; the fibrous tunic (fig. 240, 1) is much thinner, is less white in colour, and contains more elastic tissue; the trabeculæ are finer and more equal in size; the areolæ are smaller, more uniform, and directed for the most part with their long diameter in the line of that of the penis; in the glans, the meshes are smallest and most uniform. Plain muscular fibres immediately surround the canal of the urethra, and also form part of the external coat of the cavernous substance.

Blood-vessels.—**Arteries.**—A considerable artery, derived from the *internal pudendal*, enters the bulb on each side, and supplies the greater part of the cavernous body, sending branches as far as the glans penis, but this part is chiefly supplied by branches from the *arteria dorsalis*. Besides these, there is another, but much smaller, branch of the pudendal artery, entering the bulb on the upper surface, about an inch from its posterior extremity, and running forwards in the corpus cavernosum to the glans (Kobelt). The arteries open into the venous spaces chiefly, if not entirely, by the intervention of capillaries. **Veins** issue from the glans and adjoining part of the spongy body, to end in the *vena dorsalis penis*; those of the rest of the cavernous body for the most part pass backwards through the bulb, and end in the *prostatic* and *pudendal venous plexuses*; some emerge from beneath the corpora cavernosa penis, anastomose with their veins, and end partly in the *cutaneous veins of the penis and scrotum*, and partly in the *obturator* veins.

The **lymphatics** of the cavernous tissue are described as issuing from the cavernous bodies and passing under the pubic arch with the deep veins, but their termination is not known.

The **nerves** of the erectile parts of the penis accompany the blood-vessels, and consist of both vaso-dilator and vaso-constrictor fibres. They come from both lumbar and sacral nerves. The exact path, in the human subject, of the fibres corresponding to the nervus erigens (vaso-dilator) of the penis of the dog is not known, but they arise from the sacral spinal nerves—probably the third and fourth.

URETHRA VIRILIS.

The male urethra extends from the neck of the bladder to the extremity of the penis. Its total length when moderately stretched is about 20 cm., but it varies with the length of the penis, and the condition of that organ. Except during the passage of urine or semen, the walls of the canal are in close apposition, the outline of the urethral cleft being vertical in the glans penis, transverse in the body of the penis, and crescentic about the middle of the prostatic part. Its diameter when moderately distended differs at different parts, as will be stated more particularly hereafter. The tube consists of a continuous mucous membrane, supported by an outer layer of submucous tissue, connecting it with the several parts through which it passes. The urethra may be divided into two parts: a *urinary* and a *urogenital.* The urinary portion is about 1·5 cm. to 2 cm. in length, extends from the vesical orifice to the openings of the common ejaculatory ducts, and is formed from the

caudal part of the endodermal sinus urogenitalis. The urogenital part, as its name implies, serves as a channel for both the urine and the spermatic fluid. It comprises the remaining and much the longer division of the urethra, and is derived

FIG. 241.—MEDIAN SECTION OF THE MALE PELVIS AND URETHRA. Three-fifths natural size. (J. Symington.)

BL., bladder; P.S., pubic symphysis; P, P′, prostate; BU., bulb of corpus cavernosum urethræ; M, membranous portion of urethra; S, cavernous portion; G, glans penis. For other references, see fig. 118.

from the ectodermal sinus urogenitalis. The urethra may also be divided, according to its position, into pelvic, diaphragmatic, perineal, and penile; but more commonly, its divisions are based upon its relations to the surrounding structures, and comprise **intramural, prostatic, membranous**, and **cavernous** portions.

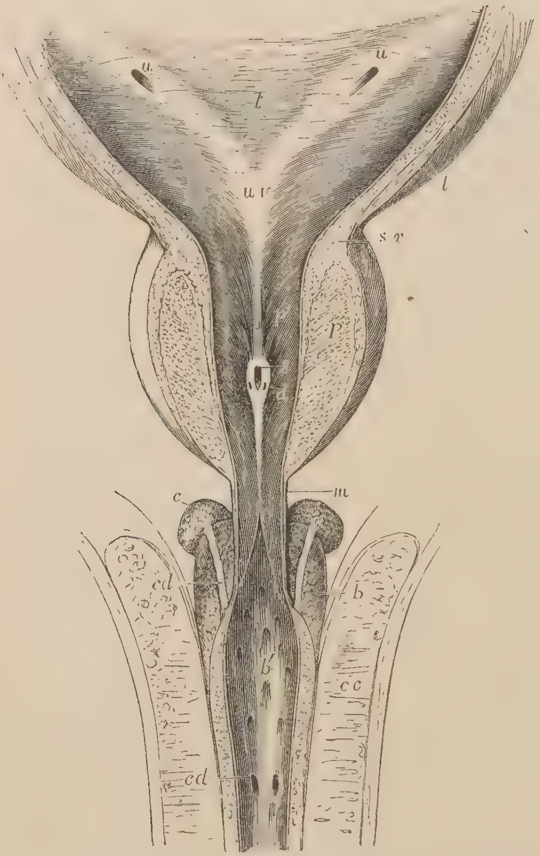


FIG. 242.—THE LOWER PART OF THE BLADDER AND THE PROSTATIC, MEMBRANOUS, AND BULBOUS PARTS OF THE URETHRA OPENED FROM ABOVE. (Allen Thomson.)

A portion of the wall of the bladder and the anterior part of the prostate gland have been removed, the corpora cavernosa penis have been separated in the middle line and turned to the side, and the urethra has been slit up; the bulb is left entire below, and upon and behind it the glands of Cowper with their ducts have been exposed. *t*, placed in the middle of the trigonum vesicæ; *u*, *u*, oblique apertures of the ureters; from these an elevation of the wall of the bladder is shown running down to *u v*, the uvula vesicæ; *l*, the longitudinal muscular fibres of the bladder passing down upon the prostate; *s v*, the circular fibres of the sphincter; *p*, the glandular part of the prostate; *p'*, the prostatic portion of the urethra; from the uvula vesicæ a median ridge is seen descending to the colliculus seminalis in which *s* indicates the opening of the prostatic utricle, and *d*, that of one of the ejaculatory ducts; *m*, the commencement of the membranous portion of the urethra; *b*, the bulb of the corpus cavernosum urethræ; *b'*, the bulbous part of the urethra; *c*, one of Cowper's glands; *c d*, *c d*, course and orifice of its duct lying upon the bulb, and passing forward between the cavernous body and the urethra, into which it opens; *c c*, one of the corpora cavernosa penis.

The **intramural portion** traverses the wall of the bladder, and is surrounded by the sphincter vesicæ internus of Henle, or sphincter urethræ lævis of Waldeyer—a muscle formed by the deep fibres of the trigone of the bladder, which pass forwards on each side of the urethra and unite in front of it. These fibres run obliquely from behind forwards and downwards, so that they unite anteriorly somewhat below the internal orifice of the urethra, which is bounded in front above the sphincter by the circular fibres of the bladder. When the bladder is contracted, this portion of the urethra is about 1 cm. long, but its length is diminished by distension of the bladder.

Opinions differ as to the capacity of the internal sphincter. According to Finger (*Alleg. Wiener med. Zeitsch.*, 1893), it can withstand the pressure of a moderate amount of urine, but when the bladder becomes fully distended it yields, and a funnel-shaped dilatation of the urethra is formed, the base of which is continuous with the cavity of the bladder, and the apex is near the lower end of the prostate, where the external vesical sphincter begins. This view is contrary to the experience of anatomists, who often meet with cases of considerable distension of the bladder with a closed vesical orifice, and it is not supported by the experiments of Leedham-Green ('On the Vesical Sphincter and the Mechanism of the Closure of the Bladder,' *Brit.*

Med. Jour., April 11, 1906), who injected the bladder during life with a fluid containing bismuth, and then radiographed the pelvis.

1. The **prostatic portion** is the part which passes through the prostate gland. It is about 2·5 cm. in length, and is the widest and most dilatable part of the canal —especially in its middle portion. Its direction is vertical, or nearly so. The trans-

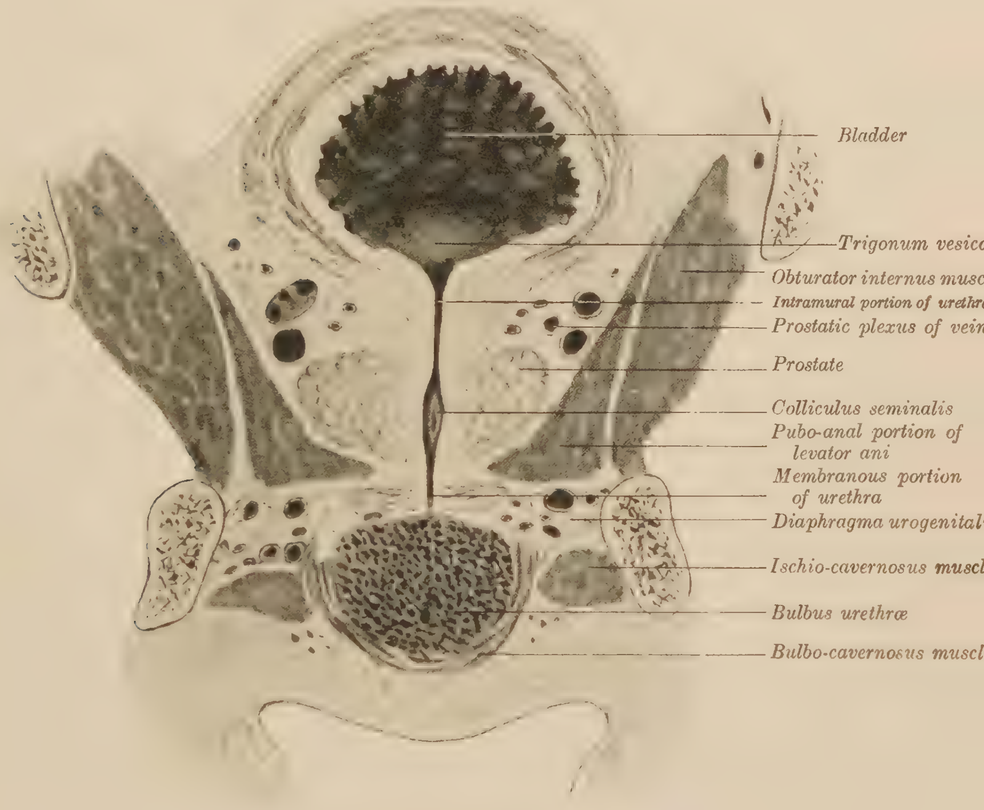


FIG. 243.—CORONAL SECTION OF THE PELVIS OF A MAN, AGED FORTY YEARS, PASSING THROUGH THE INTRAMURAL, PROSTATIC, AND MEMBRANOUS PORTIONS OF THE URETHRA. Natural size. (J. Symington.)

The muscular and connective tissue below the prostate and pubo-anal portions of the levatores ani and above the bulbus urethræ and the ischio-cavernosi muscles form the diaphragma urogenitalis. This diaphragm is bounded below by the inferior fascia and above by the superior fascia, and is traversed by the membranous portion of the urethra and by the pudendal blood-vessels and nerves.

verse section of the urethra, as it lies in the prostate, is curved with the convexity forwards. The *colliculus seminalis* (*caput gallinaginis* or *verumontanum*) is a narrow median ridge about 15 mm. long, and measuring in its greatest height about 5 mm., which projects from its posterior wall. This ridge rises into a peak and sinks down at its two extremities, the upper of which may be continuous with the uvula vesicæ at the opening into the bladder. It is formed by an elevation of the mucous membrane and subjacent tissue.

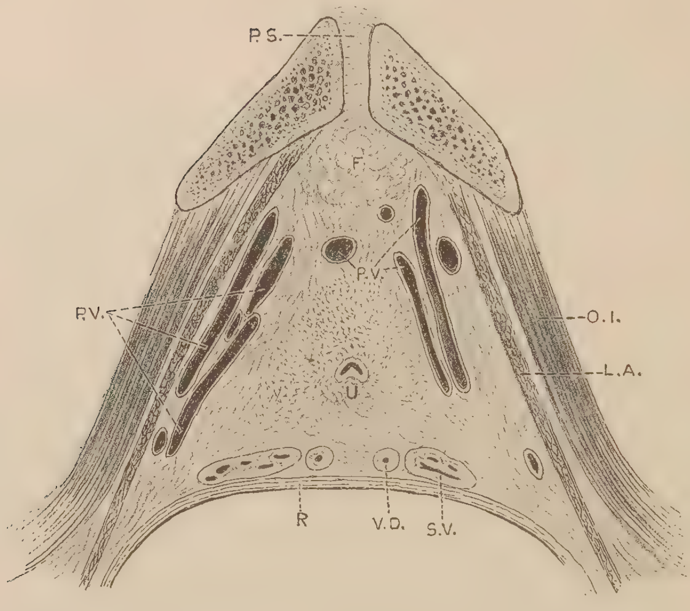


Fig. 244.—Horizontal section of male pelvis passing through the intramural portion of the urethra. The rectum was distended with fæces. Natural size. (J. Symington.)

p.s., pubic symphysis; o.i., obturator internus muscle; l.a., levator ani muscle; p.v., prostatic plexus of veins; f, retro-pubic pad of fat; u, behind urethra; r, anterior wall of rectum; v.d., ductus deferens; s.v., seminal vesicle.

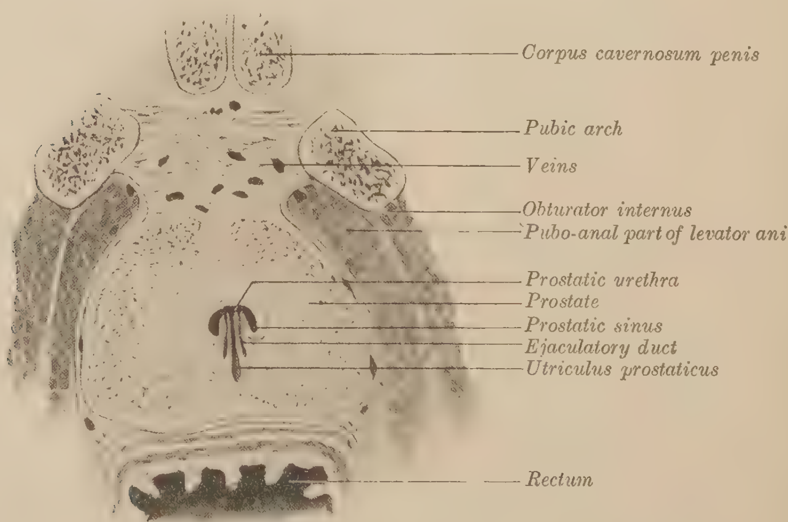


Fig. 245.—Horizontal section through the prostate, opposite the openings of the utricle and ejaculatory ducts into the urethra. Natural size. (J. Symington.)

On each side of this ridge, the surface is slightly depressed, so as to form a longitudinal groove, named the *prostatic sinus*, the floor of which is pierced by numerous foramina, the orifices of the prostatic ducts. Through these, a viscid fluid oozes out on pressure; the ducts of the middle lobe open above the urethral crest, and some others open below it.

In 1836, E. H. Weber advanced the theory that the colliculus seminalis by its erection during the ejaculation of the semen prevented this fluid from passing backwards into the bladder, and this view as to its function is still prevalent; but there is little or no cavernous tissue in the colliculus, and the other anatomical relations are not such as to facilitate this action. The semen is probably prevented from passing backwards into the urethra by the sphincter vesicæ muscle (see G. Walker, 'Beitrag zur Kenntniss der Anatomie und Physiologie der Prostata nebst Bemerkungen über den Vorgang der Ejaculation,' *Arch. f. Anat.*, 1899).

Utriculus prostaticus.—At the fore-part of the most elevated portion of the crest, and exactly in the middle line, is the orifice of a blind recess, upon or within the lateral margins of which are placed the slit-like openings of the common seminal or ejaculatory ducts, one at each side. This median opening leads into the *utriculus prostaticus*, which has been named also *sinus pocularis* and *uterus masculinus*. It was first described by Morgagni, and corresponds to the vagina and uterus in the female, its prominent lateral lips being supposed to represent the hymen.

The *utricle* (see fig. 245) forms a cul-de-sac, running upwards or backwards, for a distance of 6 mm. to 12 mm. Its orifice forms a longitudinal cleft about 2 mm. or 3 mm. in length; but the utricle increases somewhat in diameter towards its farther end or fundus. The narrow portion runs in the urethral crest, and its fundus lies behind and beneath the middle lobe, and in some cases reaches to the posterior surface of the prostate gland. Its walls which are distinct, and of some thickness, are composed of fibrous tissue and mucous membrane, together with a few muscular fibres, and enclose on each side the ejaculatory duct; numerous small ramified and convoluted glands open on its inner surface. The epithelium is columnar, and is by some authors stated to be ciliated. There are small glands opening into its cavity near its entrance into the urethra.

While the two Müllerian ducts normally atrophy in the male, and their fused caudal ends are represented merely by the utricle, a number of cases have been recorded in which these ducts undergo a marked development and unite to form an organ which exhibits a distinct division into uterus and vagina. The uterus may be as large as in the adult female, and differentiated into a body and a cervix—the latter having a well-marked arbor vitæ, while the vagina is provided with rugous walls. In these cases, the uterus projects into the pelvic cavity between the bladder and the rectum, and has a broad ligament. The uterus is often two-horned, but the tubæ uterinæ are nearly always very rudimentary. The external genitals may be of the normal male type, so that the condition may not be discovered except during an operation or in the post-mortem room.

2. The **membraneous portion** of the urethra comprises the part between the apex of the prostate and the bulb of the corpus cavernosum urethræ. It is termed by Waldeyer the pars trigonalis, as it lies in the trigonum urogenitale of the pelvic floor. It is about 1 cm. in length, and its lining membrane is thrown into numerous longitudinal folds when its lumen is closed. It is directed downwards and slightly forwards beneath the pubic arch, the anterior slightly concave surface being distant about 2 cm. from the pubic symphysis, leaving an interval occupied by the dorsal vessels and nerves of the penis, by areolar tissue, and muscular fibres. Its posterior convex surface is turned towards the rectum, and is related to the bulbo-urethral or Cowper's glands. Above, is the prostate and the superior fascia of the urogenital diaphragm and below the inferior fascia separating it from the bulb (see fig. 243). Its lower end, where it pierces the inferior fascia, is the narrowest

and least dilatable part of the urethra. Outside the submucous coat, there are non-striped muscular fibres, consisting of internal longitudinal and external circular fibres. These fibres are continuous above with those of the prostate, and below end mainly in the framework of the bulb. Continuous with the outer aspect of the non-striped fibres is the deep transverse perineal muscle, which is striated, and forms the sphincter urethræ striatus of Waldeyer.

3. The **cavernous portion** of the urethra, by far the longest and most variable in length and direction, includes the remainder of the canal, or that part which is surrounded by the erectile tissue of the corpus cavernosum urethræ. Its length is about 15 cm., and it extends from the urogenital diaphragm to the orificium urethræ externum. The direction of the cavernous portion of the urethra varies in different parts of its course, and under different conditions. Thus it inclines forwards and downwards for a short distance above the bulb, and then turns forwards and somewhat upwards to about the middle of its length, where in the flaccid condition of the penis it usually bends sharply downwards to the external orifice (see fig. 241). During erection of the penis, or when this organ is drawn forwards, as in passing a catheter, this temporary curve is obliterated, and the cavernous part is straight from the external orifice to the neighbourhood of the bulb. The part contained within the bulb—sometimes distinguished as the *bulbous portion*, or *sinus*—is somewhat dilated. The succeeding portion, as far as the glans, is of uniform diameter, being intermediate in this respect between the bulbous and membranous portions. The cross-section of its canal appears like a transverse slit. The canal of the urethra in the glans has, on the contrary, when seen in a cross-section, the form of a vertical slit; in this part, which is about 1 cm. in length, the canal is again dilated, forming what is named the *fossa navicularis*.

Lastly, at its orifice—which is a vertical fissure 5 mm. to 6 mm. in extent, and bounded by two small lips—the urethra is again contracted. From the resistant nature of the tissues at its margin, this opening does not admit so large a sound or catheter as the other parts of the urethra, with the exception of the junction of the bulbous and membranous portions.

The corpus cavernosum urethræ which surrounds this part of the urethra has been described in the account of the anatomy of the penis. Between this body and the mucous membrane there are a few scattered muscular fibres.

The **mucous membrane** of the urethra is lined by several layers of epithelium, which varies in different parts of the urethra (see Vol. II., Pt. 1). The epithelium rests on a basement membrane. Outside the mucous membrane, there is a layer of convoluted vascular tissue; and external to this structure, from the internal orifice to the bulb, is a double layer of plain muscular fibres, the inner disposed longitudinally and the outer circularly.

As already mentioned, the muscular fibres surrounding the urethra are collected in two situations, so as to form sphincters: namely, in the intramural and membranous portions; and the experience of surgeons in cases of removal of the prostate tends to show that either can act as a sphincter and prevent incontinence of urine.

The whole lining membrane of the urethra, except near the external orifice, is beset with small racemose mucous glands and follicles, commonly named the *glands of Littré*, the ducts of which pass obliquely forwards through the membrane. They vary much in size and in the extent to which their cavities are ramified and sacculated, some being quite simple. Besides these, there are larger recesses or *lacunæ*, opening by oblique orifices turned forwards, or down the canal. These are most

abundant along the roof of the urethra, especially in its bulbous part. One large and conspicuous recess, situated on the upper surface of the posterior part of the fossa navicularis, is named the *lacuna magna* or *sinus of Guérin.* A median fold of the mucous membrane separating this lacuna from the lumen of the urethra has been named the *valve of the fossa navicularis.*

Stratified concrements, like those met with in the prostate are also found in old subjects in the glandular recesses of the urethra (Robin and Cadiat).

Curvature of the urethra.—The urethra forms a somewhat S-shaped curve in the flaccid state of the penis. The anterior curve is due to the pendent position of the penis, and can readily be obliterated by drawing this organ upwards and forwards. The posterior curve has its convexity directed backwards and downwards, and it is often described as the *pars fixa urethræ*, although it can be obliterated without any permanent injury—as in the passage of a straight catheter into the bladder. It owes its usual fixation mainly to its connexions with the pelvis through the pubo-prostatic ligaments, the superior and inferior fasciæ of the urogenital diaphragm, and the suspensory ligament of the penis. The most fixed part of the curve is where the urethra traverses the urogenital diaphragm, *i.e.* the membranous portion. The urethra above this diaphragm (prostatic and intramural portions), and that part situated below and in front of the perineal division of pars cavernosa urethræ, are more subject to variations in position: the former according to the condition of the bladder and rectum, and the latter on the amount of fat in the mons pubis and the condition of the suspensory ligament. A distension of the rectum pushes the prostatic urethra forwards and upwards; while with a distended bladder and an empty rectum, the urethra is moved downwards and backwards and also shortened. In thin subjects, the anterior limb of the pars fixa is not carried so far forwards in thin as in stout individuals (compare figs. 210 and 211).

Traced from the front, the pars fixa of the urethra usually passes backwards, with a slight inclination downwards, until it reaches the bulb, which is the most dependent part. At the bulb, the urethra generally makes a rather sharp bend upwards before passing through the inferior fascia. The membranous and prostatic portions of the urethra are approximately vertical in direction, but they often form a slight curve with the convexity backwards. Near the bladder, there is sometimes a sharp bend from below upwards and forwards—especially in cases of enlargement of the middle lobe of the prostate—so that the point of a catheter requires to be tilted well forwards in order to get it into the bladder. (For further details and references to literature, consult F. Merkel, 'Ueber die Krümmung der Pars fixa urethræ,' *Anat. Anzeig.*, Bd. xxiii., 1903.)

Calibre of the urethra.—As the urethra is a closed tube with a more or less folded lining membrane, the calibre is indicated by the size of the stream of urine during micturition. The general calibre may be estimated by the size of catheter that can be passed along the urethra in the living body without injury to its walls; and the relative dilatability of its different parts can be determined after death by making casts with fusible metal. The adult urethra should permit of the passage of an instrument 10 mm. in diameter as a maximum. Eberth gives the diameter of a metal cast as 4·5 mm. at the union of the bulbous and membranous portions: at the external orifice, 5 mm. to 7 mm.; in the middle of the prostatic urethra, 11·3 mm.; and opposite the bulb, 16·8 mm. The semen probably collects in this dilatation of the bulbus urethræ before ejaculation.

Variations of penis and urethra.—The prepuce may fail, more or less

completely, to develop. In the condition known as phimosis, the prepuce cannot be retracted so as to uncover the glans. Sometimes this is due to the prepuce being unusually long and the annulus præputialis contracted; more commonly, however, it arises from a persistence of the fetal condition, when the opposing surfaces of the glands and the prepuce are united by epithelium. This is often described as adherent prepuce or congenital phimosis (see Berry Hart, 'On the Rôle of the Developing Epidermis in Forming Sheaths and Lumina to Organs, Illustrated especially in the Development of the Prepuce and Urethra,' *Jour. Anat. and Phys.*, vol. xlii., October 1907; and F. Wood Jones, 'The Development and Malformations of the Glans and Prepuce,' *Brit. Med. Jour.*, January 15, 1910).

There may be a defective development of the urethral wall, so that a fissure extends backwards from the meatus along the upper surface of the penis, giving rise to the condition called epispadias, or the cleft may be on the under-surface (hypospadias). In epispadias, the fissure may be limited to the anterior part of the penis, or extend along its whole length and be combined with ectopia vesicæ. It is supposed by some to be due to a rupture of the cloacal membrane; by others, to a persistence of the caudal end of the primative groove. Hypospadias is usually limited to the glans, but may pass backwards on the under-surface of the body of the penis and even reach the perineum. Hypospadias is due to a failure of union of the two lips of the median groove on the under-surface of the genital tubercle. If it be combined with a small penis and a non-descent of the testes, the external genitals may simulate those of the female. In rare cases, epispadias and hypospadius may be combined and form a cleft penis.

Glandulæ bulbo-urethrales (*Cowper's glands*).—These two glands lie just above the posterior end of the bulb, from which they are separated merely by the inferior fascia of the urogenital diaphragm. In front of the glands is the membranous portion of the urethra, and their median surfaces are almost in contact. The artery to the bulb runs forwards and inwards, being first external to, and then below, the gland, and in its course gives one or more twigs to the gland. The fibres of the compressor urethræ lie above and behind it.

The gland is of firm consistence, of a yellowish colour, and is generally compared in size to a pea. In young adults, it measures nearly 1 cm. in both the transverse and antero-posterior diameters, and about 5 mm. from above downwards. It appears to atrophy in old age, and one or both may be absent. Each gland is provided with a duct about 3 cm. in length, which lies first between the bulb and the membranous urethra, next in the cavernous substance, and then beneath the mucous membrane, and terminates in the floor of the bulbous part of the urethra by a minute orifice.

These glands are compound racemose, and consist of several lobules held together by a firm investment. This latter, as well as the walls of the ducts, contains muscular tissue. The glands secrete a viscid fluid—the use of which is not known.

Occasionally, there is a third glandular body in front of, and between, Cowper's glands; this has been named the *anterior prostate* or *ante-prostatic gland*.

PROSTATA.

The prostate gland (figs. 241, 243, and 245) is an organ connected with both the urinary and male genital ducts, but it primarily belongs to the latter, being one

of the accessory male organs of generation. It atrophies in the adult after the testicles are excised, and when these organs are removed in infancy it remains undeveloped. In animals it enlarges, like the testicles, during the breeding season.

It is a firm, glandular, and muscular body, comparable in size and shape to a chestnut, situated in the pelvis, and traversed by the prostatic part of the urethra and by the common ejaculatory ducts. It has a base, an apex, an anterior convex, and a posterior flat surface. The *base* is situated immediately below the neck of the bladder. Its central portion, which surrounds the urethra, is continuous with the bladder, while the peripheral portion is separated from this organ by a deep groove, occupied mainly by a plexus of veins. Dixon has shown that this groove is horizontal posteriorly; but on each side it slopes from behind forwards and downwards. The *apex* rests on the urogenital diaphragm. The *posterior surface* consists of an upper and a lower portion, which are separated from one another near the median plane by the fissure containing the ejaculatory ducts. The small upper portion is in relation with the ductus deferentes and the seminal vesicles, while the lower and larger portion is in contact with the rectum. This lower part is flat or sometimes concave, and is the part of the gland which can be felt *per rectum*. The *anterior surface* is convex from side to side, and consists of two lateral portions separated in front by a rather ill-defined anterior border or median portion. On each side, this surface is rounded and prominent, and covered by the pubo-anal part of the levator ani muscle, external to which is the obturator internus muscle. The median part is placed about 10 mm. to 15 mm. behind the lower portion of the pubic symphysis, from which it is separated by some fat, fascia, and a plexus of veins, and the pubo-prostatic ligaments. The urethra passes through the prostate from its base to its apex in the median plane, and rather nearer the anterior than the posterior surface, being generally about 6 mm. from the former and nearly 12 mm. from the latter. The prostate is also pierced by the two common ejaculatory ducts, which enter at a median depression situated at the upper part of the posterior surface, and, passing downwards and forwards in close contact with one another, open on the posterior wall of the prostatic portion of the urethra. In a median section (fig. 241), the prostate is therefore seen to be divisible into three parts: one in front and two behind the urethra. Of the two posterior portions, one lies above and in front, and the other below and behind, the channel for the ejaculatory ducts.

The prostate is usually described as consisting of three lobes: two lateral and one median. The *lateral lobes* form the great mass of the gland, and are united with one another in front of the urethra, and also behind the urethra, below the ejaculatory ducts. The *middle lobe* lies behind the upper portion of the urethra, below the apical portion of the trigone of the bladder and above the common ejaculatory ducts. At the sides, it passes without any line of demarcation into the lateral lobes. This part of the prostate is of considerable surgical interest since, when enlarged, it may seriously interfere with micturition. Its title to be regarded as a distinct 'lobe' is disputed. Sometimes it projects backwards, as a rounded prominence, between the bladder and the ductus deferentes; but, according to H. Thompson, this only occurs when it is pathologically enlarged. According to J. Griffiths, it contains, in some subjects, glandular tissue, and the ducts of the glands are distinguishable from those of the lateral lobes by opening on the posterior surface of the upper part of the prostatic urethra in and near the middle line. In other cases, neither glandular tissue nor ducts are present in this position. The prostatic part of the urethra receives not only the openings of the seminal and prostatic ducts, but also, as has

already been more particularly described, that of a small blind recess, called the *prostatic utricle,* which passes backwards in close relation with the ejaculatory ducts.

Size and weight.—The longest diameter of the prostate is the transverse, which measures, near the base of the organ, about 35 mm.; its vertical extent is about 30 mm., and its antero-posterior nearly 20 mm. These diameters, however, are liable to alteration, according to the condition of the bladder and rectum. Thus distension of the bladder tends to diminish its vertical extent, while a dilatation of the lower part of the rectum will compress the organ from before backwards, and increase its vertical and transverse diameters. Its average weight is about 20 grms. to 25 grms.

Structure.—The prostate gland is covered by a strong layer of fascia forming the sheath of the prostate. This sheath is a part of what is often termed the visceral pelvic fascia. On the lateral aspect of the prostate (see fig. 243), the sheath invests veins lying in the groove at the junction of the prostate and bladder, and above these veins it becomes continuous with the thinner fascial covering of the bladder. External to the lateral portion of the sheath is the levator ani. At the apex of the prostate, the sheath sends outwards a layer which passes below and in front of the levator ani as the superior fascia of the urogenital diaphragm. The sheath investing the vesico-prostatic plexus of veins extends upwards and outwards on the visceral surface of the levator ani, as the lateral true ligament of the bladder, to the white line or arcus tendineus of the pelvic fascia. At the posterior part of the lateral aspect of the prostate, the sheath is continuous with the fascia on the side of the rectum (see fig. 245), and it also extends inwards, forming a strong covering on the posterior surface of the prostate, and a thinner layer on the front of the rectum. This sheath on the back of the prostate is continuous above with the fibrous investment covering the ductus deferentes and the vesiculæ seminales, while below it joins the superior fascia. The fascial relations on the front of the prostate are more complicated. In the median plane, a thin and on each side a thicker band of fascia extends backwards from the pubic bones to the prostate, forming the *ligamenta pubo-prostaticum medium et lateralia.* These ligaments join the prostate a little below the union of the prostate and bladder, and above their attachment a small part of the prostate is covered by the vesical sheath. Below these ligaments, there is an area on the prostate which lies in relation with a mass of fibrous tissue, mixed with some non-striped muscular fibres, in which are embedded a plexus of veins. This tissue extends downwards to the superior fascia, and outwards to the levatores ani muscles. Internal to the prostatic sheath, is the prostatic capsule which forms a layer of fibro-muscular tissue about 1 mm. thick, and is closely adherent to the prostatic tissue. The prostatic plexus of veins do not lie between the sheath and the capsule, but are embedded in the sheath (Thomson Walker).

The proper substance of the prostate is composed of glands embedded in a stroma consisting mainly of muscular tissue. This muscular tissue forms an external layer below the fibrous sheath, and extends everywhere through the glandular substance. The part of the prostate in front of the urethra is almost entirely muscular, and consists partly of striped fibres forming the sphincter vesicæ externus of Henle; in the hinder part, the muscular tissue is best developed near the bladder.

The glandular substance is spongy and yielding; its colour is reddish grey, or sometimes of a brownish hue. It consists of numerous tubular alveoli, arranged to form forty to fifty lobules, the ducts from which open by from twelve to twenty or more orifices upon the floor of the urethra, chiefly in the hollow on each side of the

colliculus seminalis. The epithelium is shortly columnar or vertical throughout, and there is a second layer of small cells next to the basement membrane. In the upper part of the gland, the acini are smaller and more saccular; in the middle and lower parts, the tubes are longer and convoluted at their ends. The capillary blood-vessels form a close network, as in other similar glands, on the ducts and acini, and the different portions of the gland are united by areolar tissue, and supported by processes of the deep layer of the fibrous capsule and by the muscular stroma.

Blood-vessels, lymphatics, and nerves.—Arteries.—The principal artery to the prostate is the inferior vesicle; it occasionally gets branches from the superior vesicle and inferior hæmorrhoidal, and the internal pudendal gives a few twigs, which enter near the apex of the gland. The vessels ramify in the capsule, and send branches between the lobules, and from these, smaller branches pass into the lobules and supply the glandular tissue.[1] The veins pass partly towards the surface of the gland and partly to the submucous coat of the urethra. The larger veins are found in front of the prostate and on each side between the prostate and the bladder. From this plexus vesico-prostaticus, the blood reaches the pudendal vein by the inferior vesicle. The **lymphatic vessels** are abundant in the prostate; they end in a lymphatic gland near the obturator canal and in the hypogastric glands. The **nerves** come from the hypogastric plexus, and along the lateral borders of the gland there are numerous nerve-cells.

Secretion.—Examined after death, the prostatic fluid has a milky aspect, due to the admixture of a large number of epithelial cells; but, during life, it is probably more transparent. It is not a mucous secretion but, according to Adams, the fluid has an acid reaction, and presents, under the microscope, numerous granules, epithelial cells, and nuclei. Some of the granules are composed of lecithin (Fürbringer, *Jena. Sitzungsb.*, 1881). It appears to be an important constituent of the seminal fluid, having a stimulating action on the movements of the spermatozoa.

Peculiarities according to age.—The prostate is very small at birth, and it remains comparatively so until puberty, when, in common with the other generative organs, it undergoes a considerable increase in size. It is frequently the seat of a pseudo-hypertrophy of its glandular tissue in old age.

The glandular tissue of the prostate is developed by epithelial outgrowths from the posterior wall of the urethra at the sides of the orifices of the primitive genital ducts, both Müllerian and Wolffian (Griffiths). These gland-tubules grow outwards to form the lateral lobes of the prostate, and by their extension forwards and inwards, may meet in the median plane in front of the urethra. The amount of gland-tissue in front of the urethra is very small in the child, and in some cases it is not developed in this situation at any period of life. Griffiths considers that the median lobe, when present, is not formed by a fusion of the lateral lobes behind the urethra, but arises independently by median outgrowths from the upper part of the posterior wall of the urethra. The prostate exhibits a marked tendency to undergo enlargement in old age, and its tubules frequently contain small laminated bodies, which gradually become calcified.

ORGANA GENITALIA MULIEBRIA.

The genital organs in the female consist of a pair of glands called the *ovaries*, and of certain passages leading from the peritoneal cavity to the exterior. These passages may be divided into a pair of lateral ducts, the *tubæ uterinæ* (Fallopian tubes) and a single median passage, which consists of three main portions, named from above downwards, the *uterus*, *vagina*, and *urogenital space* or *pudendal cleft*. Fig. 246 shows diagrammatically the general relations of these parts. The structures

[1] G. Walker, 'The Blood-vessels of the Prostate Gland,' *Amer. Jour. Anat.*, vol. v., 1905.

which bound the urogenital space constitute the *external genitals*, while those above the hymen are the *internal genitals*.

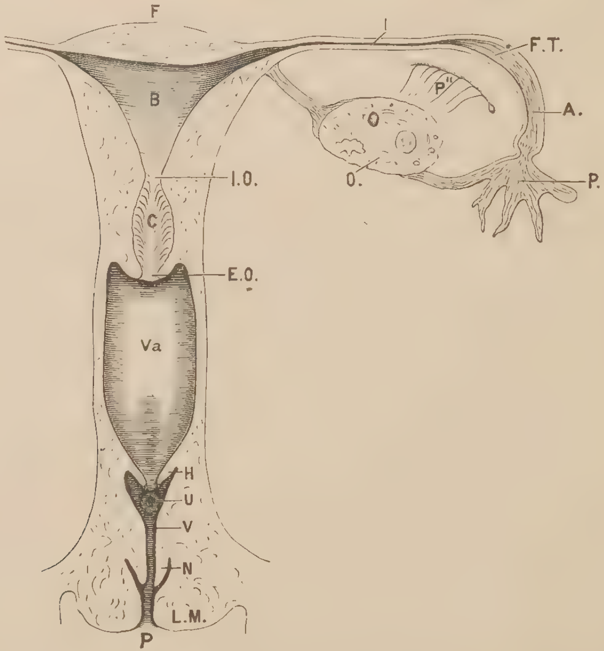


FIG. 246.—DIAGRAM OF FEMALE GENITAL PASSAGES. Modified from Henle. (J. Symington.)

O., ovary; P''., parovarium; F.T., tuba uterina [Falloppii]; P'., infundibulum tubæ uterinæ; A., ampulla tubæ uterinæ; I., isthmus tubæ uterinæ; F., fundus of uterus; B., cavity of body of uterus; I.O., orificium internum uteri; C., cavity of cervix of uterus; E.O., orificium externum uteri; VA., vagina; H., hymen; U., orifice of urethra; V., vestibule; N., labium minus; L.M., labium majus; P., pudendal or vulval cleft. The passage from U. to P. constitutes the urogenital space.

OVARIA.

The ovaries (ovaria) are two ductless female glands, homologous with the testicles in the male. They contain numerous ova which are embedded in closed sacs known as the Graafian follicles (folliculi oophori). Ova are discharged from the ovaries by the periodic rupture of the Graafian follicles and the escape of their contents into the peritoneal cavity—a process known as ovulation.

Shape and size.—Each ovary is a somewhat flattened oval body and possesses a median and a lateral surface, an upper or tubal and a lower or uterine extremity, a posterior free convex border (margo liber), an anterior attached border (margo mesovaricus), and a hilum at the mesovarian border for the entrance or exit of blood-vessels, &c. The ovary is about 25 mm. long, 15 mm. broad, and 10 mm. thick; but it not only varies in size in different individuals, but also in the same subject, according to the state of its functional activity.

Position and relations.—The position of the ovary is by no means constant, and opinions are divided as to the condition which is to be regarded as normal. According to His,[1] Waldeyer,[2] and the majority of recent observers, the ovary in the adult nullipara is placed against the side wall of the pelvis, with its long

[1] 'Ueber Praeparate zum Situs viscerum,' u.s.w., *Arch. f. Anat.*, 1878; and 'Die Lage der Eierstöcke in der weibl. Leiche,' *Arch. f. Anat.*, 1881.
[2] *Das Becken*, Bonn, 1899.

axis vertical, in the erect position of the body. Kölliker,[1] however, describes it as lying obliquely in the pelvis with its long axis parallel to the external iliac vessels, and Hasse,[2] while admitting that the ovary may be considered as normally occupying the position described by His, believes that it is frequently drawn towards the uterus by the plain muscular fibres contained in the broad ligament, so that its long axis is then directed obliquely downwards and inwards. Adopting the account

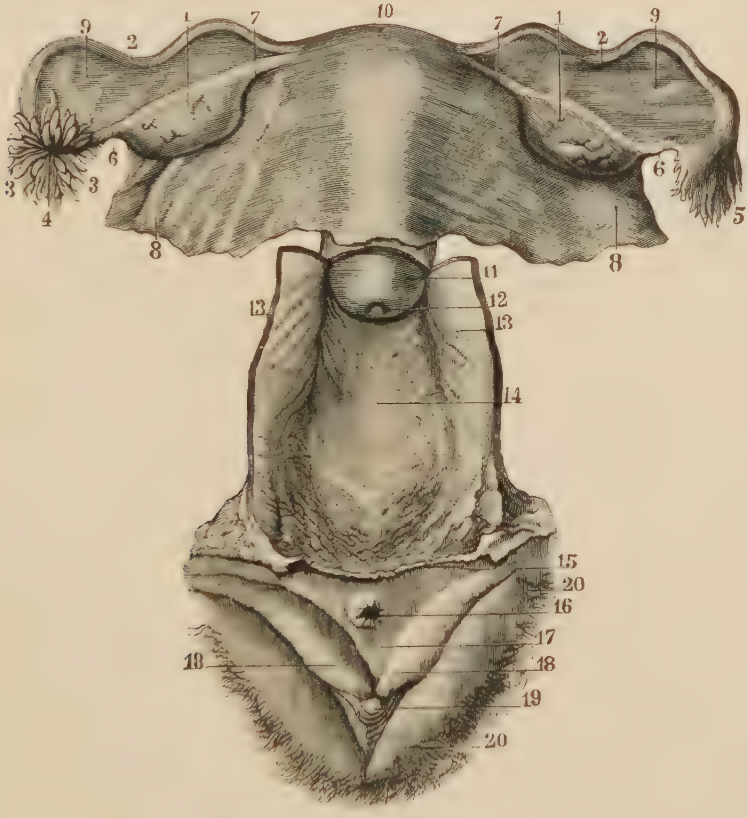


FIG. 247.—VIEW OF THE FEMALE ORGANS OF GENERATION FROM BEHIND, THE VAGINA BEING CUT OPEN AND ITS WALLS TURNED ASIDE. One-half natural size. (Sappey.)

1, ovaries; 2, tubæ uterinæ; 3, 4, 5, their fimbriated extremities (4 points to the ostium abdominale); 6, ovarian fimbria; 7, ligament of the ovary; 8, 9, broad ligaments; 10, uterus; 11, its vaginal portion; 12, orificium externum uteri; 13, lateral and posterior walls of vagina reflected; 14, its anterior wall; 15, edge of hymen; 16, orifice of urethra; 17, vestibule; 18, labia minora pudendi; 19, glans clitoridis; 20, labia majora pudendi.

given by His as representing the usual position of the ovary, we will now describe its relations.

The **median surface** is free and covered to a variable extent by the uterine tube and the adjacent portion of the mesosalpinx. The tube and its mesentery

[1] *Ueber die Lage der weibl. inneren Geschlechtsorgane*, Bonn, 1882.
[2] 'Beobachtungen ueber die Lage der Eingeweide im weibl. Beckeneingange,' *Arch. f. Gynaekologie* Bd. viii.

may cover the whole of the median surface, so as to separate it from direct contact with other structures. Some convolutions of the jejuno-ileum are often found on the inner side of the right ovary, and occasionally also the vermiform process, while the pelvic colon may have a similar relation to the left ovary (fig. 250).

The **lateral surface** is also free and lies against a more or less distinct peritoneal depression on the side wall of the pelvis, termed the *fossa ovarica*. This depression lies below the prominence formed by the psoas and external iliac vessels, in front of the ureter and uterine artery and behind the lateral umbilical ligament. Waldeyer,[1] who maintains that the fossa must be regarded as of normal

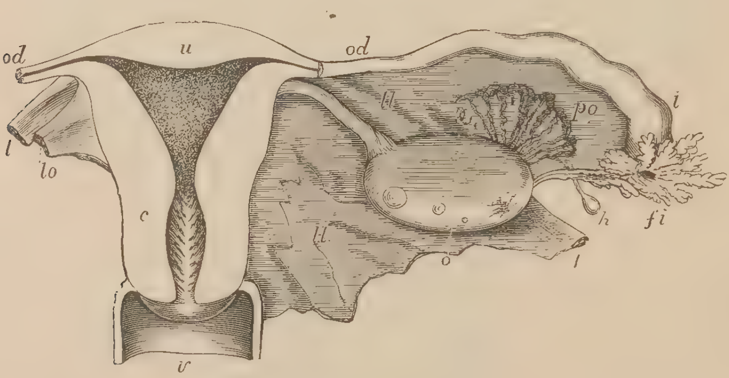


FIG. 248.—DIAGRAMMATIC VIEW OF THE UTERUS AND ITS APPENDAGES, AS SEEN FROM BEHIND. Two-thirds natural size. (Allen Thomson).

The uterus and upper part of the vagina have been laid open by removing the posterior wall; on the left side of the tuba uterina, round ligament and ovarian ligament have been cut short, and the broad ligament removed; *u*, the fundus of the uterus; *c*, the cervix opposite the orificium internum; the triangular shape of the uterine cavity is shown, and the dilatation of the cervical cavity with the rugæ, termed arbor vitæ; *v*, upper part of the vagina; *od*, tubæ uterinæ; *l*, round ligament; *lo*, ligament of the ovary; *o*, ovary (here represented with its long axis horizontal, although in the natural position within the body it is oblique or nearly vertical); *i*, wide outer part of the right tuba uterina; *f i*, its fimbriated extremity; *po*, parovarium; *h*, one of the hydatids frequently found connected with the broad ligament.

occurrence, admits that it varies considerably in depth, and may be farther back than usual, so that the ureter is opposite the anterior edge of the fossa instead of the posterior. The lateral surface of the ovary is separated from the bony wall of the pelvis by the parietal peritoneum, a quantity of loose fascia and fat containing the obturator nerve and some blood-vessels, and most externally by the obturator internus muscle.

The **posterior border** is free, convex, and turned somewhat inwards towards the rectum. Like the median surface, it is covered partially by the fimbriated end of the uterine tube. The **anterior border** is straighter than the posterior: it gives attachment to a short mesovarium, between the two layers of which is the hilum, where the blood-vessels and nerves enter the ovary. The uterine tube ascends in front of this border. To its upper extremity is attached the ovarian fimbria of the uterine tube, and also a peritoneal fold, termed the *ligamentum suspensorium ovarii*, which passes downwards from the brim of the pelvis and

[1] 'Topographical Sketch of the Lateral Wall of the Pelvic Cavity, with Special Reference to the Ovarian Groove,' *Jour. Anat. and Phys.*, vol. xxxii., October 1897.

contains the ovarian vessels and nerves. The uterine tube bends backwards at the upper end of the ovary. The lower end of the ovary is generally narrower than the upper, and is attached to the uterus by the ligament of the ovary. This extremity does not normally reach the floor of the recto-uterine peritoneal pouch, so that the ovary is suspended against the side wall of the pelvis.

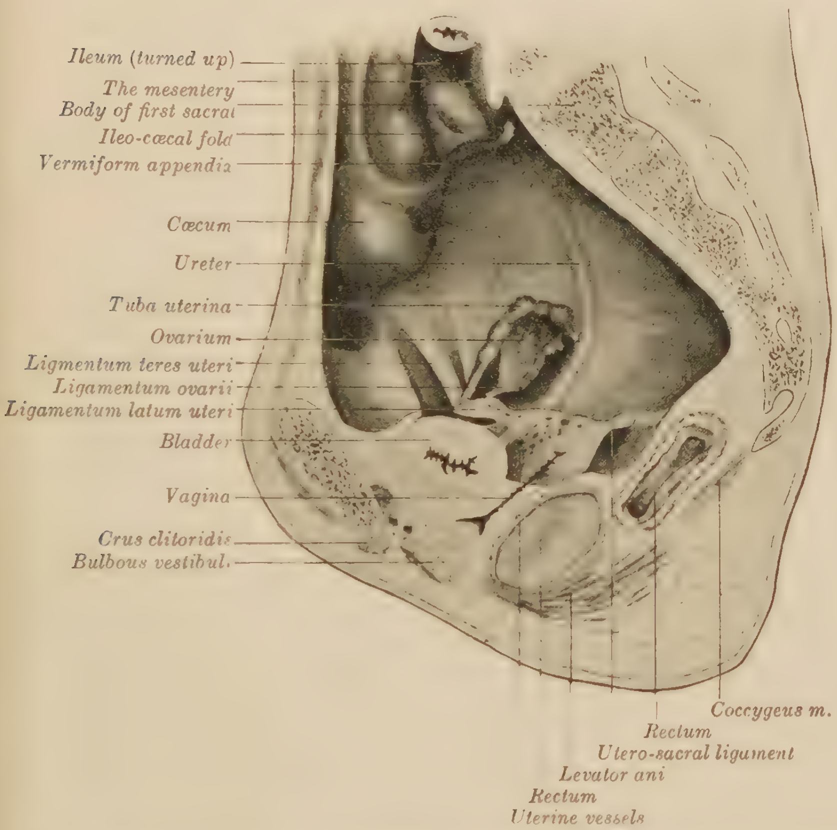


FIG. 249.—SAGITTAL SECTION OF THE PELVIS OF A FEMALE, AGED TWENTY-FOUR YEARS, MADE ABOUT 12 MM. TO THE RIGHT OF THE MEDIAN PLANE, AND VIEWED FROM THE MEDIAN ASPECT. One-half natural size. (J. Symington.)

After this section was made, the uterus and the upper part of the vagina were divided still farther to the right of the median plane. The convolutions of the jejuno-ileum were removed from the pelvis in this and the following figure.

Structure.—The surface of the ovary has a dull greyish colour, which is easily distinguished from the white shining appearance of the mesovarium. It is not covered by peritoneum, but by a layer of columnar cells—the remains of the germ epithelium. Farre[1] drew attention to a white line along the attached border of the ovary, and Waldeyer[2] showed its significance as indicating the termination of the ordinary peritoneal endothelium. During the child-bearing period of life,

[1] 'Uterus and its Appendages,' *Todd's Cyclopædia of Anatomy and Physiology*, vol. v., 1859.
[2] *Eierstock und Ei*, 1870.

the surface of the ovary often exhibits a number of vesicles, which vary in size and prominence. Some of these may be seen to have a thin, semi-transparent covering and to contain a clear fluid. On section, the ovary is found to consist of a firm stroma, which at the surface forms a rather ill-defined tunica albuginea. Embedded in the stroma are the Graafian follicles, in various stages of develop-

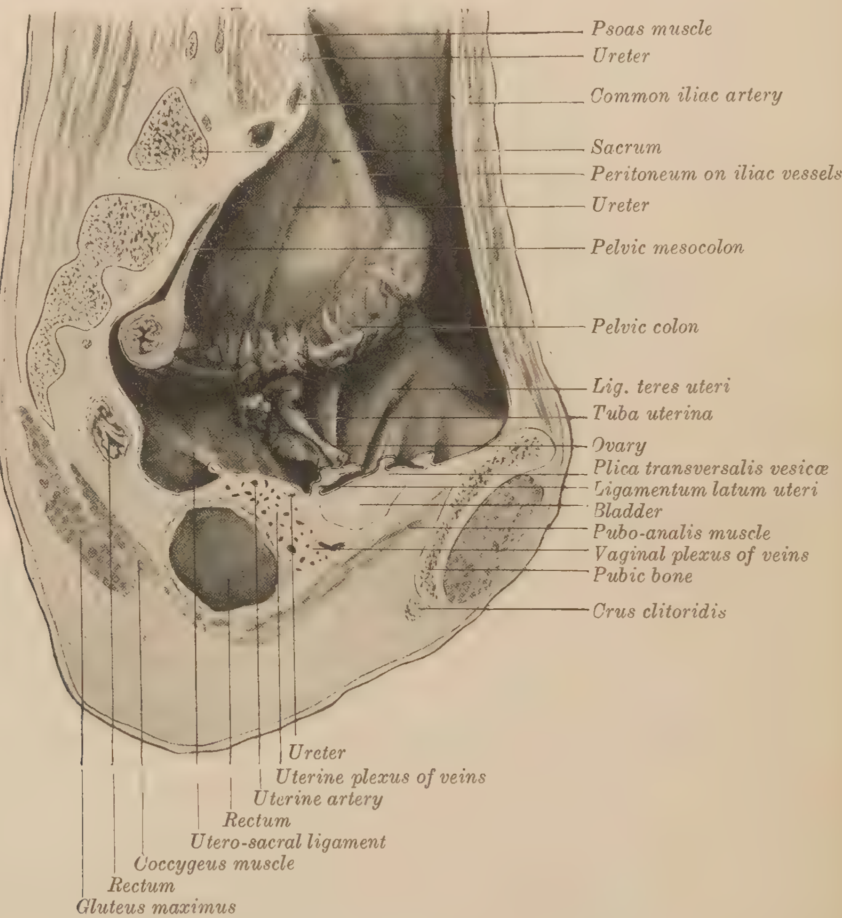


Fig. 250.—Sagittal section of the pelvis of a female, aged twenty-four years, made about 2·5 cm. to the left of the median plane, and viewed from the median aspect. One-half natural size. (J. Symington.)

ment, and each containing a microscopic ovum. A corpus luteum may be present, and also the atrophied remains of several corpora lutea, forming small whitish masses known as the corpora albicantia.

Peculiarities according to age.—In the young fetus, the ovary lies in front of the psoas muscle near the kidney and having the uterine tube on its outer side. From this position it gradually passes downwards and inwards, so that at birth it lies at the brim of the pelvis with its lower and inner end projecting slightly into the pelvis, and its upper and outer part in the iliac fossa. During fetal life the ovary is long, narrow, and soft, showing impressions due

to the pressure of adjacent intestine; but soon after birth, it becomes firmer and more oval in form.

Until puberty, its surface is smooth; but after the process of ovulation is fully established it tends to become uneven. This is due to the laceration of the surface by the rupture of the Graafian follicles and the cicatrisations that occur in connexion with the closure of the openings. In old age the ovary undergoes atrophy, becoming more fibrous and less vascular.

Varieties.—The above description of the position and relations of the ovaries is based upon the examination of adult nulliparæ, with the bladder empty and the uterus ante-flexed and ante-verted. The ovaries, however, are not firmly fixed in any one place, and even in the same individual their position is liable to vary according to the condition of the other pelvic organs. Thus, if the uterus be moved upwards and backwards, by distension of the bladder or other causes, the ovaries will be displaced backwards towards the sacrum. His found

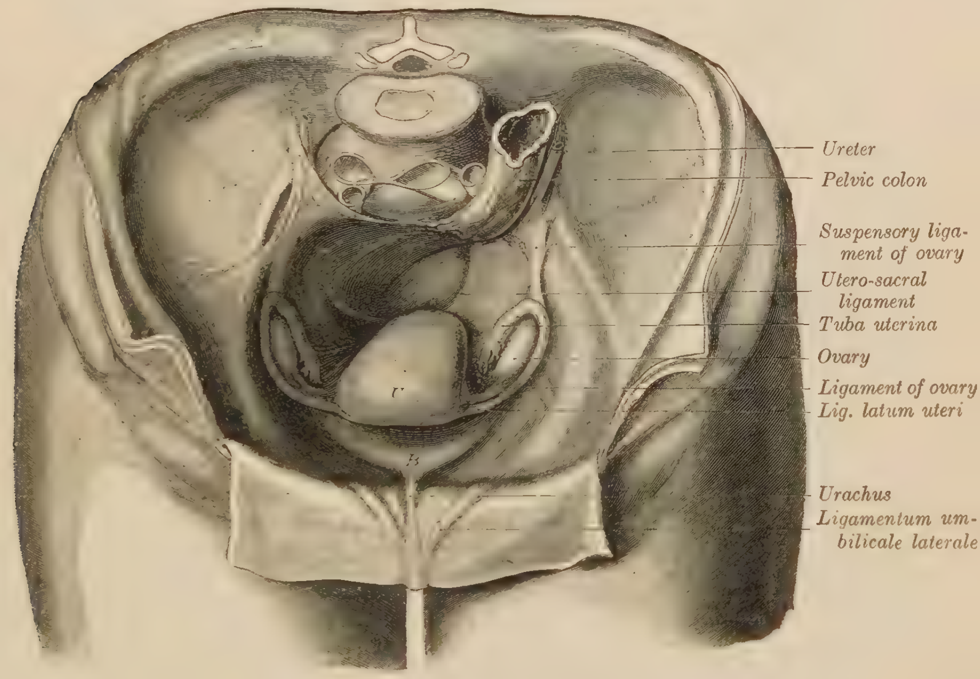


FIG. 251.—PELVIC ORGANS OF THE FEMALE, VIEWED FROM ABOVE. (v. Bardeleben and Haeckel.)
U, uterus; *B*, bladder.

that in cases of lateral deviation of the uterus, the ovary on the side towards which the uterus lies, is vertical; while the lower end of the opposite ovary is drawn towards the median plane by the ligament of the ovary, so that its long axis becomes oblique. Waldeyer, however, has recorded a case in which the ovary on the side opposite to the uterine deviation maintained its vertical position against the side wall of the pelvis, apparently on account of the ligament of the ovary being longer than usual on that side. As a rule, the ovary on the side towards which the uterus is displaced is distinctly higher than the one on the opposite side. Thus in a specimen of Waldeyer's, the one ovary had its upper end 1 cm. below the level of the external iliac vein, and the other ovary reached as high as the upper border of the corresponding vein. Waldeyer states that he has not seen any cases, such as Hasse describes, where a normal ovary lies in contact with the uterus.

Absence of one or both ovaries is extremely rare. Occasionally, the ovary retains its infantile form until adult life. It is very uncommon to find it remaining in its primitive position near the kidney, but sometimes in place of descending into the pelvis it takes a similar course to that of the testicle, passing into the inguinal canal and even through the external abdominal ring to the labium majus. When enlarged it frequently becomes prolapsed, passing downwards

and inwards behind the uterus, so that when both ovaries are enlarged they may meet near the median plane. The presence of accessory ovaries has been described by Waldeyer and others. Beigel ('Ueber accessorische Ovarien,' *Wiener med. Woch.*, 1877) found them present in eight out of 350 cases. They may be sessile or pedunculated, and are usually small. In all

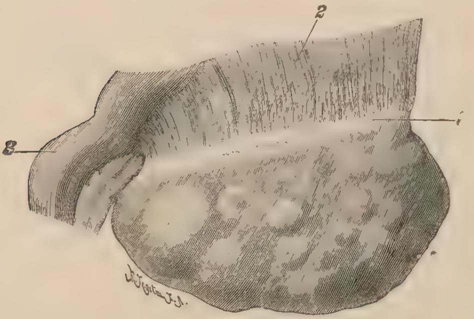


FIG. 252.—SURFACE OF A HUMAN OVARY. (W. Nagel.)

1, line of separation between peritoneum and tunica albuginea of ovary; 2, mesovarium; tuba uterina with ovarian fimbria.

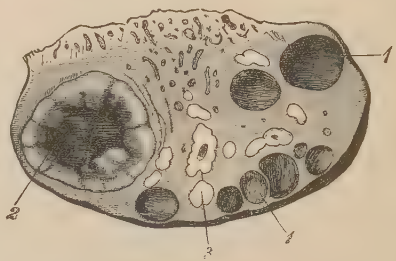


FIG. 253.—SECTION OF A HUMAN OVARY. (W. Nagel.)

1. 1, Graafian follicles; 2, corpus luteum; 3, corpus albicans.

probability they represent detached portions of the ovary. Cavalie (*Bibliog. anat.*, t. ix., 1901) reported a case in which the right ovary was divided into two distinct portions.

Blood-vessels, lymphatics, and nerves of the ovaries.—Arteries.— The ovary is supplied by the ovarian and the uterine arteries. The ovarian gives several branches directly to it, and others arise from a twig going to the fimbriated end of the uterine tube. The branch from the uterine artery passes outwards between the two layers of the broad ligament to anastomose with the ovarian, and supply a number of small vessels to the ovary. The arteries of the ovary are long and tortuous, and reach the hilum between the two layers of the mesovarium. From the hilum they ramify freely in its substance, and are accompanied by nonstriped muscular fibres. The veins are considerably dilated and tortuous in the hilum and the mesovarium, forming a swelling, termed by Rouget the bulb of the ovary. Most of the veins leaving the ovary ascend in the suspensory ligament as the ovarian plexus of veins, but some join the uterine veins. The *lymphatics* of the ovary are abundant. At the hilum, they form a dense network, known as the plexus sub-ovaricus. Six to eight lymphatic vessels ascend with the ovarian blood-vessels and terminate in the aortic glands. Poirier describes an anastomosis with the uterine lymphatic vessels, but Bruhns failed to detect this connexion.

FIG. 254.—SECTION OF THE OVARY OF THE CAT. (Schrön.)

1, outer covering and free border of the ovary; 1′, attached border; 2, the central ovarian stroma, presenting a fibrous and vascular structure; 3, peripheral stroma; 4, blood-vessels; 5, Graafian follicles in their earliest stages lying near the surface; 6, 7, 8, more advanced follicles, which are embedded more deeply in the stroma; 9, an almost mature follicle containing the ovum in its deepest part; 9′, a fold which the ovum has accidentally escaped; 10, corpus luteum.

FIG. 255.—SECTION OF INJECTED OVARY FROM A GIRL OF SIXTEEN. Magnified about 8 diameters. (J. G. Clarke.)

A, ovarian artery; a, a′, its deeply lying parallel branches which are seen giving off arterioles towards the superficial parts; V, ovarian veins; b, a corpus luteum; c, c, Graafian follicles; d, d, unruptured follicles which are in process of atresia; e, a more complete stage of atresia (corpus albicans).

The ovary is well supplied with both vaso-motor and sensory nerves, derived from the ovarian plexus on the ovarian vessels. According to some authorities, the ovary contains a number of nerve-cells of the sympathetic type.

Epoophoron (parovarium, or organ of Rosenmüller) is a flattened structure with a trapezoid or rarely a triangular outline, situated in the lateral part of the mesosalpinx, between the ovary and the uterine tube. It consists of about fifteen small ducts (*ductuli transversi*), 1 cm. to 2 cm. in length, passing transversally between the ovary and the uterine tube, and a longitudinal duct (*ductus epoophori longitudinalis*) running parallel to the outer part of the uterine tube. The epoophoron can usually be brought into view by holding the mesosalpinx between the eye and a bright light, but it is often obscured by the presence of fat and blood-vessels. The ducts are adherent to the ventral layer of the mesosalpinx, but are only loosely connected with the dorsal layer.

The transverse ducts may be divided into three sets: upper or lateral, intermediate, and lower or median. The intermediate are the most numerous, and they usually converge towards the hilum of the ovary near its tubal extremity. On microscopic examination, these ducts are found to form a network at the hilum of the ovary, termed the rete ovarii. The upper ducts (or Kobelt's tubules [1]) end above the ovary, near the free margin of the mesosalpinx, in small dilated extremities, which may project into a special fold of the ventral layer of the mesosalpinx as small cyst-like bodies, some of which may become pedunculated. A few rudimentary lower ducts do not penetrate the ovary. As the transverse ducts pass towards the uterine tube, they often become tortuous, and end by joining the longitudinal duct (fig. 256).

The longitudinal duct (Gartner's duct) usually corresponds in length to the base of the epoophoron, but it may extend laterally beyond this body to terminate in a pedunculated cyst, and medially may be traced between the layers of the broad ligament to the side of the uterus.

Paroophoron.—This is a small rounded body, situated in the mesosalpinx, median to the epoophoron, and composed of a few rudimentary tubules. It can usually be detected with the naked-eye during the first year after birth.

The epoophoron is the remains of the upper (sexual) part of the Wolffian body and duct, while the paroophoron is derived from a few of the lower or urinary tubules of the same body. The paroophoron persists throughout life, but it appears to be better developed during the period of sexual activity.

TUBÆ UTERINÆ.

The two **tubæ uterinæ** (*Fallopian tubes*) may be considered as ducts of the ovaries (oviducts) since they serve to convey the ova from these glands into the uterus. They differ, however, from the ducts of all the other glands in the body in being detached from the organs whose secretions they convey. They are enclosed in the free margin of the broad ligaments in the whole of their extent, except the intra-mural portions, which traverse the uterine wall for about 1 cm. to open into the uterine cavity. Traced from the uterus—to the superior angles of which they are attached—they are found to pass almost horizontally outwards, for a distance of from 1 cm. to 2 cm., until they reach the side walls of the pelvis, against which they ascend, frequently in a tortuous manner, in front of their corresponding ovaries, and then arch backwards above these glands and internal to their suspensory ligaments (fig. 249). Finally, they turn downwards, so that the fimbriæ are opposite the inner

[1] *Der Neben-Eierstock des Weibes*, Heidelberg, 1847.

surfaces and posterior borders of the ovaries. Some convolutions of the small intestine are often situated above and internal to both tubes. The vermiform process, when projecting downwards into the pelvis, comes into close relation with the right tube, while the pelvic colon is often in contact with the left tube. The average length of the tubes is 10 cm. to 12 cm., and, as a rule, the right one is a little longer than the left.

Each tube may be divided into an *isthmus*, an *ampulla*, a *neck*, and a *fimbriated extremity*. The *isthmus* corresponds to about the inner third of the tube; it is straight, round, and cord-like, and has a diameter of 2 mm. to 3 mm. Its lumen communicates with the uterine cavity by an orifice which will barely admit a hog's bristle, and is not dilatable. From this opening, its cavity enlarges as it passes outwards, but only very gradually. The *ampulla* extends from the isthmus to the neck, and forms rather more than one-half of the total length of the tube. It differs from the isthmus in its larger size, in its dilatability, in being less firm to the touch, and by its tortuous course. This part of the tube increases in size from the isthmus to the neck, and its average diameter is 6 mm. to 8 mm., while in many cases it will admit, in the greater part of its length, a No. 6 to No. 8 catheter. Ballantyne and Williams[1] found that the orifice at the *neck* of the tube, or *ostium abdominale*, was physiologically closed in tubes removed during life, while in specimens obtained from the post-mortem room it was somewhat gaping. When moderately distended, it has a diameter of 3 mm. or 4 mm. The ovarian end of the tube expands in a trumpet-shaped manner from the neck to enclose a space called the *infundibulum*

TWO FIGURES EXHIBITING A COMPARISON BETWEEN PARTS OF THE GENERATIVE ORGANS IN THE TWO SEXES.
(From Farre, after Kobelt.)

FIG. 256.—ADULT OVARY, EPOOPHORON, AND TUBA UTERINA. (Kobelt.)

a, a, epoophoron (parovarium) formed from the upper part of the Wolffian body; *b*, remains of the uppermost tubes, sometimes forming hydatids; *c*, middle set of tubes; *d*, some lower atrophied tubes; *e*, atrophied remains of the Wolffian duct; *f*, the terminal bulb or hydatid; *h*, the tuba uterina, originally the duct of Müller *i*, hydatid attached to the extremity; *l*, the ovary.

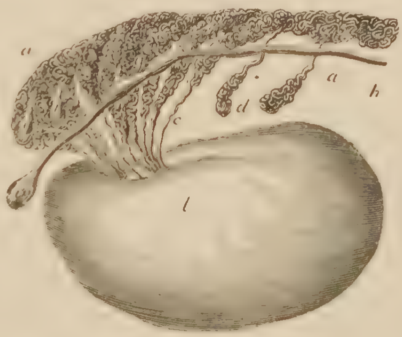


FIG. 257.—ADULT TESTIS AND EPIDIDYMIS. (Kobelt.)

a, a, convoluted tubes in the head of the epididymis developed from the upper part of the Wolffian body; *b* and *f*, hydatids in the head of the epididymis; *c*, coni vasculosi; *d*, vasa aberrantia; *h*, remains of the duct of Müller with *i*, the hydatid of Morgagni, at its upper end; *l*, body of the testis.

[1] *The Structures in the Mesosalpinx*, Edinburgh, 1893.

or *pavilion* and is then prolonged into a number of irregular processes called *fimbriæ*: hence the term *fimbriated extremity.* From its irregular torn appearance, it was named by the ancient anatomists *morsus diaboli.* The fimbriæ vary considerably in number, size, and complexity. The larger ones have numerous smaller processes attached to their edges, and their inner surfaces present folds continuous with those lining the pavilion. One of the fimbriæ, which is longer than the others, is attached to the upper end of the ovary. This, the *ovarian fimbria*, has a longitudinal groove leading from the pavilion to the ovary, and bounded at its sides by secondary fimbriæ. In some cases this fimbria does not reach the ovary, but is attached to it by a ligament.

Peculiarities according to age.—In the new-born child, the uterine tubes are not situated entirely in the cavity of the true pelvis, their outer ends lying in the iliac fossæ. The ampullary part of the tube shows one to three spiral twists, and the edges of the ovarian fimbria are not fringed. In old age, the tubes tend to become narrower and straighter, and their muscular coat atrophies.

Varieties.—A pedunculated cyst, known as the *hydatid of Morgagni*, is sometimes found attached to one of the fimbriæ or to the tube itself. Ballantyne and Williams (*The Structures in the Mesosalpinx*, Edinburgh, 1893) found it in 8 per cent. of the adult cases they examined. It is lined by a mucosa provided with a single layer of ciliated columnar epithelium, its walls contain a muscular coat composed of circular and longitudinal fibres, and it is covered by peritoneum. Its structure and attachments show that, like the uterine tube, its origin is from the Müllerian duct. It is probably derived from a portion of the duct situated above the ostium abdominale. The long pedicle which it frequently possesses may be due to the extension of the duct into the fold passing from the Wolffian body to the diaphragm, and the traction exerted upon it during the descent of the Wolffian body. One or more smaller fimbriated openings not infrequently occur at a short distance from the main one. Congenital absence of a part or the whole of a tube occasionally occurs, even in cases where the uterus is properly formed (see Spencer and Doran, 'Absence of the Fallopian Tubes and of Menstruation,' *Brit. Med. Jour.*, October 1, 1910; and Spencer, 'Absence of the Fallopian Tubes and of Menstruation' (a second case), *Brit. Med. Jour.*, January 28, 1911).

Structure.—The walls of the tube are composed of a serous, a subserous, a muscular, a submucous, and a mucous coat. The serous coat is incomplete, being absent at the attachment of the mesosalpinx, where the blood-vessels, lymphatics, and nerves reach the tube. The subserous coat (tunica adventitia) is composed of delicate connective-tissue, so that the tube lies somewhat loosely in its serous fold. The muscular coat is composed of non-striped fibres, arranged in an external longitudinal and an internal circular layer. The submucous tissue contains, like that of the uterus, multipolar ganglion cells. The mucous membrane lining the tubes is thrown into longitudinal plicæ, which are broad and numerous in the wider part of the tube, and in the narrower part are broken up into very numerous arborescent processes. It is continuous, on the one hand, with the lining membrane of the uterus, and at the other end of the tube with the peritoneum, thus presenting an example of the direct continuity of a mucous and serous membrane, and making the peritoneal cavity in the female an exception to the ordinary rule of serous cavities, *i.e.*, of being perfectly closed to the exterior. The epithelium in the interior of the uterine tube is, like that of the uterus, columnar and ciliated; the inner surface of the fimbriæ is also provided with cilia. On their outer or serous surface it passes into the pavement epithelium of the peritoneal membrane. It does not appear that there are glands, as was at one time supposed, in the mucous membrane lining the uterine tubes, although the appearances of the folds of mucous membrane may simulate tubular glands (fig. 258).

Blood-vessels, lymphatics, and nerves.—The uterine tube is supplied by branches of the uterine and ovarian arteries, which anastomose with one another

and send numerous small twigs to the tube. The veins correspond to the arteries, and form a rich network in the submucous coat and between the muscular fibres. A few lymphatic vessels pass in the broad ligament to a network at the hilum of the

FIG. 258.—TRANSVERSE SECTION OF TUBA UTERINA, SHOWING FOLDED MUCOUS MEMBRANE AND WELL-DEVELOPED INTERNAL CIRCULAR AND LESS WELL-MARKED EXTERNAL LONGITUDINAL MUSCULAR LAYERS. (F. H. A. Marshall.)

ovary, and from those vessels proceed outwards and upwards to end in the lumbar glands. Sympathetic nerve-fibres accompany the blood-vessels.

UTERUS.

The uterus or womb is a hollow muscular organ, with very thick walls, situated in the pelvic cavity between the rectum and the urinary bladder. The uterine tubes, extending from each upper angle of the uterus to their ovarian opening, conduct the ovum from the ovary to the uterine cavity. In the case of pregnancy, the uterus receives the ovum, retains and supports it during the development of the fetus, and expels it at the time of parturition. During gestation, the uterus undergoes a great enlargement in size and capacity, as well as important structural changes.

Shape and size.—In the fully developed virgin condition—which is that to which the following description mainly applies—the uterus is a flattened pear-shaped body, with an upper and larger free end, and a lower extremity which projects into the vagina, dorsal (facies intestinalis), and ventral (facies vesicalis) surfaces, and right and left margins. It is usually described as consisting of a fundus, a body, and a neck. Its average dimensions are 7·5 cm. in length, 5 cm. in breadth at its upper and wider part, and 2·5 cm. in thickness; it weighs from 33 grms. to 41 grms.

The **body** (corpus uteri) has a broad convex upper end, called the **fundus**, which projects upwards from between the points of attachment of the uterine tubes (fig. 247), while below it is continuous with the neck. Its dorsal (intestinal)

FIG. 259.—MEDIAN SECTION OF THE PELVIS OF A FEMALE AGED ABOUT THIRTY YEARS. Three-fourths natural size. (J. Symington.)

1st S., body of first sacral vertebra; P.S., pubic symphysis; B., bladder; U., urethra; UT., uterus; E.O., orificium externum uteri; US., utero-sacral ligaments, which are united with one another on posterior aspect of uterus, V., vagina; A.F., anterior vaginal fornix; P.F., posterior vaginal fornix; H., hymen; R., rectum; A.C., anal canal; *L. Min.*, labium minus; *L. Maj.*, labium majus; C., clitoris; M., fat of mons pubis; P., peritoneum; B., perineal body; A.C.B., ano-coccygeal body.

This section was made after hardening the body by the injection of a 1 per cent. solution of chromic acid, and the distension of the abdominal vessels with this fluid probably depressed somewhat the pelvic viscera.

and ventral (vesical) surfaces are both covered by peritoneum and are convex, but the latter more so than the former.

Each lateral margin (*margo lateralis*) gives attachment to the two layers of the broad ligament, which are separated from one another by a quantity of fibrous and non-striped muscular tissue, and a number of other important structures. At the point of union of the lateral margin with the fundus is a projecting angle, with which the uterine tube is connected, the round ligaments being attached a little before, and the ovarian ligament behind and beneath it (fig. 261). Below these three structures are the uterine blood-vessels, lymphatics, and nerves.

Fig. 260.—Right half of a median section of a female pelvis from which a distended rectum was removed and the utero-sacral ligament exposed. (J. Symington.)

The **neck**, or *cervix uteri*, narrower and more rounded than the rest of the organ, is about 2·5 cm. in length; it is continuous above with the body, and, becoming somewhat smaller towards its lower extremity, projects into the anterior part of the upper end of the tube of the vagina, which is united all round with the substance of the uterus, but extends upwards to a greater distance behind than in front. The cervix may be divided into two parts: *portio supra-vaginalis* and *portio vaginalis*. Of these, the supra-vaginal portion is situated at and above the attachment of the vaginal wall to the uterus, and the vaginal has a free surface projecting into the upper end of the vagina. The lower end of this—the vaginal part of the cervix—has a transverse aperture by which its cavity opens into the vagina (figs. 247, 259); this is named the *orificium externum uteri*. It is bounded by two thick lips: the posterior (*labium posterius*) of which is the thinner and longer of the two; while the anterior (*labium anterius*), although projecting less from its vaginal attachments, is lower in position, so that when the tube is closed both lips come into contact with the posterior wall of the vagina. These borders or lips are smooth in the nullipara, but after parturition they frequently become irregular, and are sometimes fissured or cleft.

The peritoneum which covers the dorsal surface of the body of the uterus is continued on to the supra-vaginal part of the cervix as far down as the place of attachment of the vagina, from which it passes on to the posterior vaginal wall. On the ventral surface, the peritoneum covering the anterior surface of the body of the uterus is usually reflected on to the bladder at about its junction with the cervix, so that the corresponding surface of the cervix is uncovered by peritoneum, and lies in direct contact with the bladder. In consequence of the peritoneum not descending so low on the ventral as on the dorsal surface of the uterus, only one

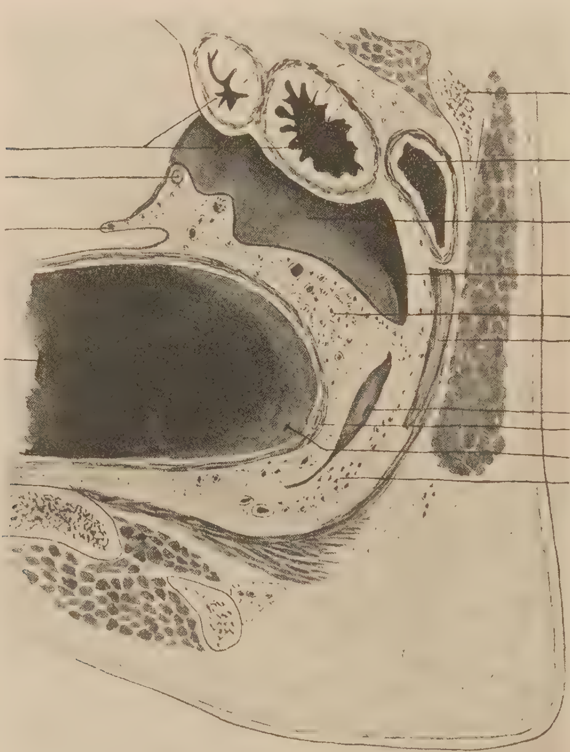


Fig. 261.—Part of a sagittal section of the pelvis of a woman aged thirty-six years, made 3 cm. to the right of the median plane and viewed from the median aspect. Two-thirds natural size. (J. Symington.)

The whole uterus was displaced towards the right side, but the fundus more than the cervix. In consequence of the distension of the bladder the uterus was pushed backwards so that it projected into the right pararectal space.

layer of peritoneum passes outwards from the side of the cervix to the pelvic wall. In front of this layer, the uterine artery courses inwards to the lateral aspect of the cervix, surrounded by a plexus of uterine veins—all these vessels being invested by connective-tissue, which is described as forming the ligament of Mackenrodt.[1] Another mass, composed of fibrous and muscular tissue and known as the *utero-sacral ligament*, extends from the sacrum to the posterior part of the lateral aspect of the cervix (fig. 260). Lateral to this ligament, the pelvic splanchnic branches, from the sacral plexus, pass to the uterus, vagina, and bladder. About 2 cm. lateral to the cervix, the ureter passes forwards and downwards to reach the bladder.

Cavity of the uterus.—The walls of the uterus are of great thickness, and the

[1] 'Ueber die Ursachen der normal u. path. Lagen des Uterus,' *Arch. f. Gynaekologie.*, Bd. xlviii., 1895.

cavity is thus proportionately much reduced in size. The part within the body is triangular (fig. 262), and flattened from before backwards, so that its anterior and posterior walls touch each other (fig. 259). The base of the triangle is directed upwards, and is convex towards the interior of the uterus. The cavity, narrowing gradually, is prolonged into its two superior angles, at each of which it leads by a minute foramen into the narrow canal of the uterine tube. At the junction of the body and the neck, the cavity is slightly constricted, and thus forms what is named the *orificium internum uteri*; this opening is often smaller than the external

FIG. 262.—OUTLINES OF MOULDS OF THE UTERINE CAVITY IN DIFFERENT STATES. Natural size. (After F. Guyon.)

A, in a virgin of seventeen years of age; B, in a woman of forty-two years, who had not borne children; C, in a woman of thirty-five years, who had borne children. *b*, cavity of the body; *c*, that of the cervix; *i*, the orificium internum uteri; *o*, orificium externum uteri; *t*, passage of the upper angle into the tuba uterina.

orifice, and is of a circular form. That portion of the cavity which is within the neck is tubular and slightly flattened before and behind; it is somewhat dilated in the middle, and opens inferiorly into the vagina by the orificium externum uteri. Its inner surface is marked by two longitudinal ridges or columns, which run—one on the anterior, the other on the posterior wall; and from both of which, rugæ are directed obliquely upwards on each side, so as to present an appearance which has been named *arbor vitæ*, or *plicæ palmatæ* (fig. 262): this structure is most strongly marked anteriorly.

Position of the uterus.—The question as to the normal position of the uterus is one that gave rise to much controversy, and regarding which very contradictory statements were made; but there is now a general agreement amongst anatomists and clinicians that the uterus does not occupy any definite fixed position, but possesses a considerable range of mobility: the chief factors that influence its position being the condition of the bladder and rectum. If both bladder and rectum be distended, the uterus lies between and in contact with these two organs, and the long axis of the uterus is approximately parallel to the axis of the part of the pelvic cavity in which it is situated. The ventral surface of the uterus generally remains in contact with the bladder (hence the term facies vesicalis); so that during micturition the uterus moves downwards and forwards, and when the bladder is empty the fundus is directed forwards, and the ventral surface more or less

directly downwards—a position described as ante-version of the uterus. This movement affects the body and fundus much more than the cervix, and hence the ventral surface becomes concave—that is, the uterus is ante-flexed. The usual normal position of the uterus, with the bladder empty, is thus one of ante-flexion and ante-version, and the dorsal surface is in contact with the convolutions of the jejuno-ileum, and the pelvic colon (facies intestinalis). As the bladder fills with urine, the body and fundus are pushed upwards and backwards, until, if the bladder be fully distended, the upper part of the uterus comes to lie near the sacrum—usually in one or other of the pararectal spaces—and the long axis of the organ to be directed from above downwards and forwards (retro-version). While retro-version may be a normal position, a bending backwards of the uterus upon itself (retro-flexion) must be regarded as pathological. The uterus is seldom quite median in position, and it often is slightly rotated on its own axis. The unimpregnated adult uterus is situated entirely in the true pelvis. The lowest part of the cervix is usually a little above the level of a line uniting the lower border of the pubic symphysis with the tip of the coccyx, and the greater part of the uterus generally lies above a horizontal plane corresponding to the top of the pubic symphysis. There are considerable individual variations in the height of the uterus, mainly depending on the degree of thickness of the pelvic floor, and its level is markedly influenced by the condition of the lower end of the rectum—distension of this portion of the bowel pushing it upwards and forwards. Gravity has also some influence: thus in the erect position of the trunk, the weight of the intestine, and the intra-abdominal pressure, will tend to depress the uterus; while in the genu-pectoral position, and the vagina opened, the organ moves upwards and forwards.

Ligaments of the uterus.—The reflexion of the peritoneum from the uterus to the bladder is called the *utero-vesical* fold, or sometimes the *anterior ligament of the uterus*. Posteriorly, as we have already seen, the peritoneum passes from the uterus on to the upper part of the vagina before being reflected backwards to the rectum, thus forming a *recto-vaginal* ligament. The peritoneal recess, situated in front of the rectum, and behind the cervix of the uterus and the upper part of the vagina, is usually termed the *pouch of Douglas* (*excavatio recto-uterina*). Two semilunar folds of peritoneum covering the utero-sacral ligaments may divide this pouch into a median and two lateral portions.

Ligamenta teretes uteri.—The **round ligaments** are two flat, cord-like bundles of fibres, about 10 cm. to 12 cm. in length, attached to the upper angles of the uterus, one on either side, immediately in front of the uterine tube. As each ligament proceeds upwards, outwards, and forwards towards the abdominal inguinal ring, it first lies between the layers of the broad ligament and raises its anterior layer into a more or less prominent fold, and then ascends on the side wall of the pelvis crossing over the obliterated hypogastric artery, the external iliac vessels, and the psoas muscle. The peritoneal fold which covers it on the lateral wall of the pelvis is continuous with that on the front of the broad ligament, and separates the para-vesical and obturator peritoneal fossæ of Waldeyer. After having passed—like the spermatic cord in the male—through the inguinal canal, the round ligament reaches the fore-part of the pubic symphysis, where its fibres expand and become united with the substance of the mons pubis. Besides areolar tissue and vessels, the round ligaments contain—chiefly in their inner third—plain muscular fibres, which are prolonged into them from the outer muscular layer of the uterine wall. Each ligament also receives a covering from the peritoneum, which, in the young subject, projects in the form of a tubular process for some distance into the inguinal canal;

this, which resembles the processus vaginalis, originally existing in the same situation in the male, is named the *canal of Nuck*; it is generally obliterated in the adult, but is sometimes found even in advanced life.

The round ligament of the uterus is derived from the plica inguinalis of the Wolffian body, which in the male forms the gubernaculum testis.

Ligamentum ovarii proprium.—The *ligament of the ovary* is merely a dense fibro-areolar cord containing some uterine muscular fibres, and measuring from 2 cm. to 3 cm. in length, which extends from the lower end of the ovary to the upper angle of the uterus, which it joins immediately below and behind the point of attachment of the uterine tube.

Ligamentum latum uteri.—The broad ligaments of the uterus (fig. 247) are formed on each side by a fold or double layer of the peritoneum, which is directed from the lateral border of the uterus to the side wall of the pelvis. Between the two layers of the serous membrane are placed the uterine tube, the round ligament of the uterus, the ovarian ligament, the epoophoron, the paroophoron, and numerous blood-vessels, lymphatics, and nerves, with fibres continuous with the superficial muscular layer of the uterus. The ovary is attached to its posterior aspect at the white line (see Ovary).

The broad ligament is a composite structure, and may be conveniently divided into a median and a lateral portion. The median part (*mesometrium*) is situated at the side of the uterus and moves with this organ, so that when the uterus is anteverted its two layers are superior and inferior and its free border is anterior, while, as the body and fundus of the uterus are moved upwards and backwards, the two layers will become anterior and posterior and the free border superior. The free border contains the uterine tube, and the ligament of the ovary and the round ligament of the uterus give rise to prominences on its posterior and anterior surfaces respectively. The lateral portion of the broad ligament is attached to the side wall of the pelvis in front of the ovarian fossa and forms two secondary folds: one connected with the uterine tube (mesosalpinx) and the other with the ovary (mesovarium). The mesosalpinx is irregularly triangular in form, with the apex towards the uterus. It is attached to the uterine tube and its ovarian fimbria, the mesovarium, and the ligament of the ovary. When spread out, it is about 8 mm. in length, and its maximum breadth, situated at the junction of its outer and middle thirds, is on an average 4 cm. (Ballantyne and Williams). It is often directly continuous with the suspensory ligament of the ovary. Owing to its breadth, the ampulla and fimbriated end of the tube have a considerable range of mobility. The *mesovarium* is a short fold attached to the anterior border of the ovary, and serving for the passage of various structures to or from the ovary.

STRUCTURE OF THE UTERUS.

The walls of the uterus consist of: (1) an outer serous coat (*tunica serosa* or *perimetrium*), (2) a subserous coat (*parametrium*), (3) a muscular coat (*tunica muscularis* or *myometrium*), and (4) a mucous membrane (*tunica mucosa* or *endometrium*). There is no submucous coat.

The serous coat, which covers the fundus and the two surfaces of the body, is very smooth and firmly adherent to the subjacent muscular fibres. At the back of the supra-vaginal part of the cervix, it is less firmly attached, and may be thrown into a few loose folds. The subserous coat is best developed round the cervix, especially at the sides, and it is also found at the lateral borders of the body of the uterus. The muscular coat consists almost entirely of non-striped fibres, which form interlacing bundles and layers, so that in the unimpregnated uterus their separation into

definite layers is impossible. The outer part of the muscular coat corresponds to the ordinary muscular coat of other hollow organs, and is only indistinctly separated by some blood-vessels from a very thick muscularis mucosæ.

The *mucous membrane of the body* of the uterus is smooth, except during the menstrual period, and in the unimpregnated state is entirely devoid of ridges; it is of a peculiar soft spongy consistence, and of a dull reddish colour, and very vascular. It consists of the uterine glands, the deeper ends of which are embedded in the muscularis mucosæ. The glands are separated by a considerable amount of inter-glandular tissue. The epithelium is columnar and ciliated.

The *mucous membrane of the cervix* is much firmer and more fibrous than that of the body. Between the rugæ of the *plicæ palmatæ* there are numerous saccular and tubular glands. In the lower part of the cervix, the mucous membrane is beset with vascular papillæ, and the epithelium is stratified; but in the upper half or more the epithelium is columnar and ciliated like that of the body. The glands, which are short, with a large lumen, are everywhere lined with columnar ciliated epithelium—even where the epithelium of the surface is stratified. Besides the follicular glands, there are almost constantly to be seen the so-called *ovula Nabothi*—clear yellowish vesicles of variable size, but visible to the naked eye, embedded in the membrane. These probably arise from closed and distended follicles; but their exact nature is still doubtful.

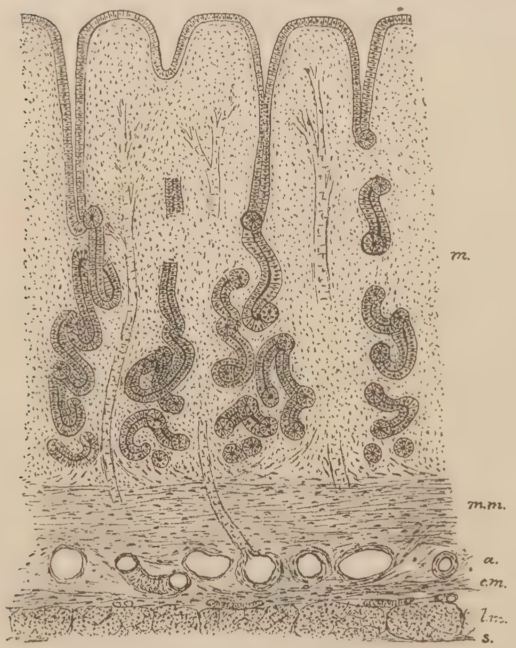


FIG. 263.—TRANSVERSE VERTICAL SECTION OF THE WALL OF ONE OF THE CORNUA UTERI OF THE RABBIT. (E. A. Schaefer.)

s., serous layer; *l.m.*, longitudinal fibres of the muscular coat; *c.m.*, circular fibres of the same; *a.*, areolar tissue with large blood-vessels; *m.m.*, muscularis mucosæ; *m.*, mucosa, with coiled glands.

During pregnancy, the mucous glands of the cervix secrete a considerable quantity of tenacious mucus, which effectually closes the passage.

The surface of the uterus, which looks towards the cavity of the vagina, is covered with stratified epithelium, concealing the vascular papillæ. It is destitute of glands.

The changes which occur in the uterine mucous membrane in connexion with menstruation and pregnancy are described in Vol. II., Pt. I. of this work.

After parturition, the uterus gradually but rapidly diminishes, till it nearly regains the size and structure of the unimpregnated condition. During this change, the enlarged muscular fibres undergo fatty degeneration, and are said to become subsequently absorbed, while a new set of fibre-cells is developed. After the first pregnancy, however, the organ never regains its original virginal character. In those who have had children, its weight usually remains from two to three ounces (102 grms. to 117 grms. Vierordt); its cavity is larger (fig. 262, C); the orificium externum is wider and more rounded, and its margins often puckered or fissured;

the arteries remain much more tortuous, and its muscular fibres and layers more defined than in the virgin.

Peculiarities according to age.—In the newly born infant, the neck of the uterus is larger than the body, and also much firmer. There is no fundus: the upper end of the uterus not forming a convex prominence between the attachments of the uterine tubes. The cavity is narrow, there is no distinct internal os, and it tapers above on both sides so as to present an approach to the two-horned form prevalent in animals. The plicæ palmatæ are very distinct, and reach to the highest point of the cavity. At this period, the uterus is usually about 3 cm. in length. It grows but slightly from birth until near puberty, at which period it undergoes a rapid and marked increase in size. This growth is especially marked in the body, which at the same time acquires a firmer consistence, while its mucous membrane becomes smooth. The cavity remains comparatively narrow in all women who have borne no children (fig. 262, B), while in those who have been pregnant it is widely triangular (C). In old age, the uterus atrophies: it becomes paler in colour and harder in texture, and its external orifice frequently becomes diminished in size.

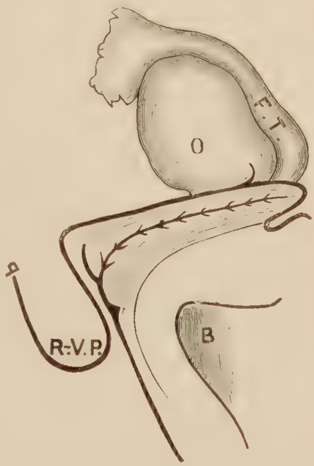


Fig. 264.—The uterus and the left tuba uterina of a girl aged thirteen years. Natural size. (J. Symington.)

The uterus is divided in the median plane, and the ovary and tube viewed from the median aspect.

Varieties.—The uterus is subject to numerous congenital defects or malformations—especially in connexion with abnormal conditions of the other genital organs. Amongst those involving the uterus may be mentioned its more or less complete absence, the occurrence of one or two horns at its upper part, and the presence of two distinct cavities. Such cases are obviously due to an imperfect development of one or both Müllerian ducts or their incomplete fusion. Occasionally, the uterus retains its infantile condition after puberty.

Blood-vessels, lymphatics, and nerves.—The **arteries** of the uterus are four in number: namely, the right and left *ovarian* (which correspond to the spermatic of the male) and the right and left *uterine*. They are remarkable for their frequent anastomoses, and also for their singularly tortuous course. After passing a short distance into the thickness of the uterine wall, they divide into branches, which penetrate the muscular tissue of the mucous membrane, supplying it with capillaries, and then pass towards the inner portion of the membrane and open into a network of large capillaries, which pervades the tissue in that situation, and is especially developed near the surface and around the glands. In the cervix, however—and especially in the vaginal portion—the arteries, which in this situation possess walls of considerable thickness, after entering the mucous membrane, divide into a number of small branches, which pass directly towards the surface and open into the capillary network there present, from which loops pass into the papillæ. The **veins** correspond to the arteries; they are very large, and form plexuses of sinus-like vessels, with thin walls in immediate contact with the uterine tissue. The **lymphatic vessels**, from the upper part of the uterus, pass outwards in the broad ligament; are joined by vessels from the uterine tube and ovary, and, ascending with the ovarian blood-vessel, end in glands situated in front of the abdominal aorta. A few vessels may also extend along the round ligament of the uterus to the superficial inguinal glands. Numerous vessels from the cervix, terminate in lymphatic glands on the side wall of the pelvis, near the origin of the hypogastric and external iliac arteries. A gland may be found in close relation to the side of the cervix.

The **nerves** are derived from the *inferior hypogastric plexuses*, the *spermatic plexuses*, and the *third* and *fourth sacral* nerves. They consist of both medullated and non-medullated fibres; and in animals small ganglia have been observed in the submucous tissue, connected with the non-medullated fibres.

VAGINA.

The vagina is a dilatable membranous and muscular passage, extending from the vestibulum vaginæ to the uterus, the neck of which is embraced by it. It passes with a slight curve from above downwards and forwards, usually nearly parallel to the plane of the pelvic inlet, but tending to become more horizontal with a

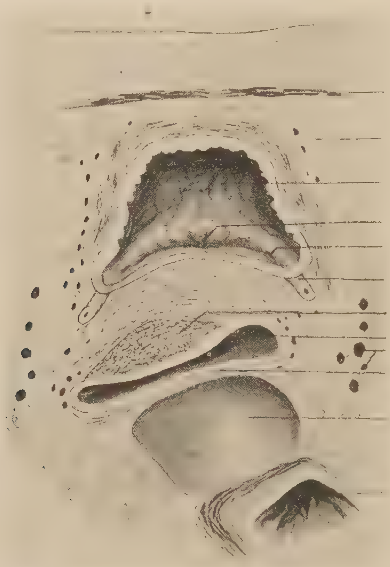


Fig. 265.—A section through the bladder, vagina, pouch of Douglas, and rectum. (J. Symington.)

This and figures 266, 267, and 268 are from a series of sections of the pelvis of a well-developed but rather fat female, aged twenty-five years. The sections passed from before backwards and somewhat downwards. Both the arteries and veins were injected. All these figures are reduced one-half.

The section shown in fig. 265 passed immediately below the reflexion of the peritoneum from the anterior abdominal wall on to the bladder, and was 2 cm. above the pubic symphysis. The bladder was opened close to its upper surface, and the labium anterius divided immediately below the orificium externum uteri. The uterus was anteverted, and rested upon the bladder with its fundus close to the anterior abdominal wall. The cavum Douglasi was occupied by intestine, and the rectum was situated to the right of the median plane.

distended bladder, and more vertical when the lower part of the rectum is loaded. The vagina varies in shape in different parts of its course. The middle portion is compressed so that its cavity forms a transverse slit, with the anterior and posterior walls in contact (see fig. 266). This slit gradually increases in breadth from below upwards, but on an average measures about 4 cm. At its upper end, the vagina expands into a circular tube to embrace the lower part of the cervix. The groove around the cervix is known as the vaginal fornix, and is divided for descriptive purposes into anterior, posterior, and right and left lateral fornices. The widest part of the vagina is opposite the lateral fornices, where it measures about 5 cm. The vagina reaches higher up on the cervix uteri, behind than in front, so that the uterus appears to project into its anterior wall (see fig. 259). The lower part of the vagina is compressed from side to side, resembling the letter H, on transverse section

(see fig. 268). The prominences on the anterior and posterior walls of the lower part of the vagina, known as the anterior and posterior columnæ rugarum, terminate

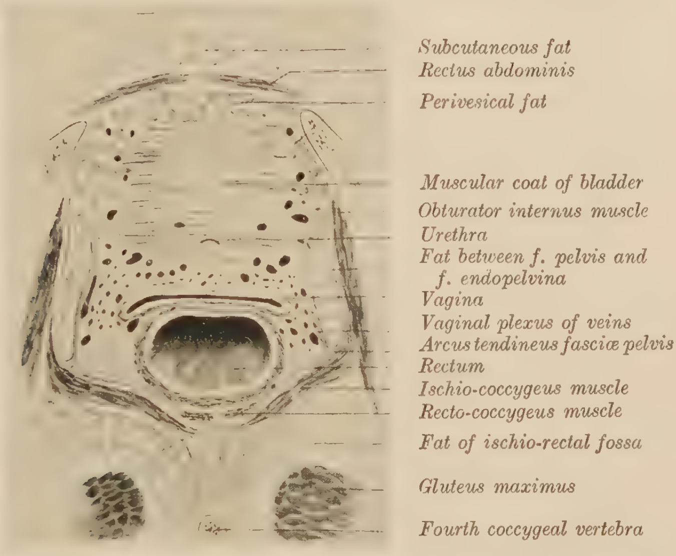


FIG. 266.—A SECTION THROUGH THE BLADDER WALL, URETHRA, VAGINA, AND RECTUM. (J. Symington.)

The urethra was divided just below the orificium urethræ internum, and is shown embedded in the bladder wall. The posterior wall of the vagina was 7 cm. long, and it is cut almost exactly in the middle of its length; while the anterior vaginal wall is divided 12 mm. below the anterior fornix vaginæ.

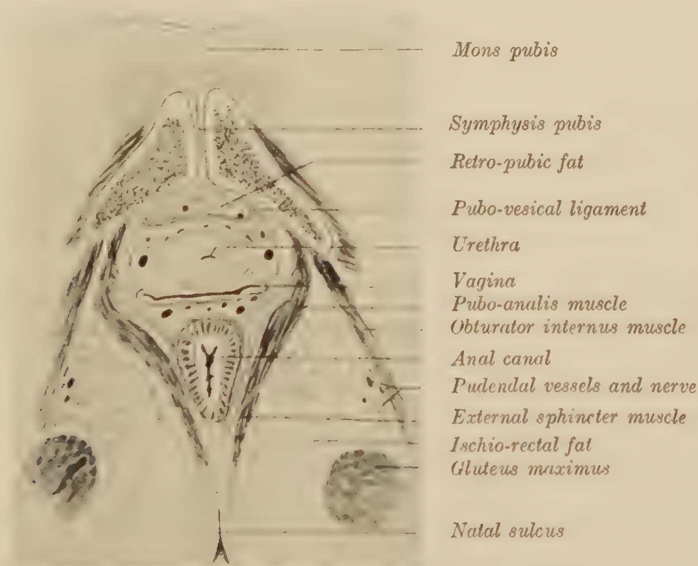


FIG. 267.—A SECTION THROUGH THE URETHRA, VAGINA, AND ANAL CANAL. (J. Symington.)

The urethra was 4 cm. long, and it is here divided 2·5 cm. below the orificium urethræ externum; while the vagina is cut about 1·5 cm. from its opening into the vestibulum vaginæ portion of the rima pudendi. The anal canal is exposed near its upper end.

just above the hymen, and the two lateral portions of the H-shaped cavity come in contact with one another, so that the vagina forms a median cleft, where it opens

below into the vestibule. The lower end of the anterior column forms a prominence, termed the *carina urethralis vaginæ*. The anterior wall of the vagina is about 6 cm. in length and the posterior 8·5 cm.

Berry Hart ('A Contribution to the Morphology of the Human Urogenital Tract,' *Jour. Anat. and Phys.*, vol. xxxv.) maintains that the lower third of the vagina, distinguished by the presence of columns, is derived from the lower ends of the Wolffian ducts and the urogenital sinus, while the upper two-thirds is Müllerian in origin. Many embryologists consider that the whole of the vagina is derived from the Müllerian ducts. Evatt ('A Contribution to the Development of the Prostate Gland in the Human Female, and a Study of the Homologies of the Urethra and Vagina of the Sexes,' *Jour. Anat. and Phys.* vol. xlv., 1911) holds that

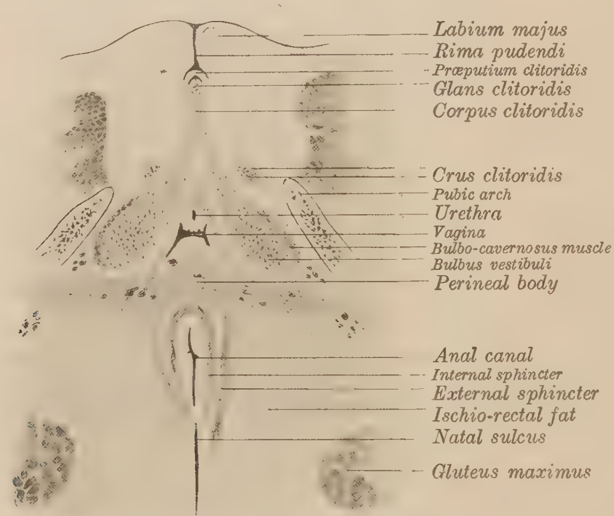


FIG. 268.—A SECTION THROUGH THE CLITORIS, VESTIBULAR BULBS, URETHRA, VAGINA, AND ANAL CANAL. (J. Symington.)

The urethra and vagina are divided just above their openings into the rima pudendi. The vestibular bulbs are continuous anteriorly with a narrow mass of rudimentary cavernous tissue—the partes intermediæ of Kobelt—which join the *clitoris*. The section is below the main mass of the corpus clitoridis, which is formed by its united corpora cavernosa.

early in the history of the female embryo, the Müllerian and Wolffian ducts open into the urethra, and the vagina is formed as a diverticulum from the inferior wall of the coalesced Müllerian ducts.

Relations.—In *front*, the vagina is in relation with the bladder, and urethra, being connected by loose areolar tissue to the bladder, but intimately blended with the urethra to form a urethro-vaginal septum. The two ureters, after passing forwards and downwards lateral to the cervix uteri, turn downwards and inwards, and pierce the bladder wall in front of the lateral fornices of the vagina. Their openings into the bladder are at about the same horizontal level as the anterior lip of the external orifice of the uterus, and the urethral orifice of the bladder is opposite near the middle of the anterior vaginal wall, so that the trigone of the bladder rests against the upper half of the vaginal wall. The *posterior vaginal wall* is usually covered in about its upper fourth or fifth by the peritoneum, forming the *excavatio recto-uterina*, or pouch of Douglas. Below this, it is loosely attached to the anterior wall of the rectum. In the upper two-thirds of their extent, the *sides* of the vagina are in relation with

the vaginal plexuses of veins, loose areolar tissue and fat separating them from the lateral walls of the pelvis. Opposite the junction of the middle and lower thirds, the two levatores ani pass backwards, lateral to the vagina and to the anal canal, to unite in the ano-coccygeal body, very few fibres turning inwards behind the vagina. These two muscles act as sphincters of the vagina—mainly by pulling forwards the anal canal and pressing it against the posterior vaginal wall. At the lower end of the vagina, the vestibular bulbs separate the sides of the vaginal orifice from the pubic arch (see fig. 268).

Structure —The walls of the vagina are composed, from without inwards, of a fibrous, a muscular, and a mucous coat ; a submucous coat is absent. The fibrous coat forms a sheath for the vagina, connects it with adjacent structures, and invests

FIG. 269.—CORONAL SECTION OF PELVIS OF FEMALE, AGED FIFTY-FOUR YEARS, PASSING THROUGH BLADDER, VAGINA, AND PERINEAL BODY. (J. Symington.)

B., brim of true pelvis ; I.T., ischial tuberosity ; O.I., obturator internus ; O.F., obturator fascia ; L.A., levator ani ; P.B., perineal body ; A.W., anterior vaginal wall ; BL., trigone of bladder. The transverse black line below A.W. represents the cavity of the vagina.

its blood-vessels and nerves. The muscular coat, which is continuous above with the muscular fibres of the uterus, is thin, and composed of non-striped muscular fibres arranged rather indistinctly into an internal circular and an external longitudinal layer. The mucous membrane is of greyish-red colour, and is firmly attached to the muscular coat. On the anterior and posterior walls, a slightly elevated ridge extends from the lower end upwards in the middle line, forming the *columns of the vagina*, or *columnæ rugarum*. Numerous dentated transverse ridges. called *rugæ*, are also observed —particularly in persons who have not borne children —running at right angles from the columns. These columns and rugæ are most evident near the entrance of the vagina and on the anterior surface, and gradually become less marked and disappear towards its upper end, except during infancy, when the rugæ extend to the upper end of the vagina. The free surface is covered by numerous layers of stratified epithelium, and the sub-epithelial tissue has papillæ and numerous elastic fibres, but no glands—or extremely few.

Blood-vessels, lymphatics, and nerves.—The vagina is largely supplied with vessels and nerves. The **arteries** are derived from branches of the

hypogastric : namely, the *vaginal*, *internal pudendal*, *vesical*, and *uterine*. The **veins** correspond ; but they first surround the vagina with numerous branches, and form at each side a plexus, named the *vaginal plexus*.

The *lymphatic* vessels, from the greater part of the vagina, ascend with those from the cervix of the uterus to terminate in the lymphatic glands on the side walls

FIG. 270.—TRANSVERSE SECTION OF VAGINA OF MONKEY, LOWER PART. (F. H. A. Marshall.)

a, stratified epithelium ; *b*, mucous membrane ; *c*, muscular coat, the fibres cut across ; *d*, a nerve ganglion ; *d*, nerves ; *e*, an artery ; *f*, fat-cells.

of the pelvis, but the lymph from the lower end of the vagina passes into the superficial inguinal glands.

The **nerves** are derived from the *hypogastric plexus* of the sympathetic, and from the spinal system by the vaginal branches of the pudendal plexus.

Varieties.—The most important malformation of the vagina is its more or less complete division into two tubes. This is due to the same cause as a double uterus : namely—failure of union of the two Müllerian ducts. As a rare abnormality, may be mentioned the non-union of the caudal ends only of the Müllerian ducts ; so that while the uterus and the upper part of the vagina are single, the lower end of the vagina is divided. Congenital obliteration of the lumen of the lower part of the vagina sometimes occurs.

HYMEN FEMININUS.

The hymen is a thin vascular fold of mucous membrane, which is situated at the vaginal orifice, and narrows this opening so that it will usually only admit the little finger; hence it is generally regarded as evidence of a *virgo intacta*.

It usually forms an annular membrane, much broader behind, where it is attached just above the fossa navicularis, than in front, where it arises about 5 mm. to 10 mm. behind the urethral orifice. The fold projects towards the exterior, and is compressed from side to side, and the opening appears as a vertical slit bounded by lateral lips, the vaginal surfaces of which are in close apposition.[1] It is only when it is exposed by forcible separation of the lateral walls of the pudendal cleft that it appears as an annular or a crescentic fold with the edges projecting inwards. Its free edge is usually smooth, but sometimes notched—*hymen fimbriatus*. In rare cases, the hymen forms a complete partition between the vagina and vulva, giving rise to the condition known as 'imperforate hymen.' It has been described as occasionally cribriform, and even in some cases as entirely absent. The small rounded elevations called *carunculæ myrtiformes*, found in women who have borne children, are probably the remains of the hymen. The vaginal surface of the hymen shows a few folds continuous with the rugæ of the vagina, and the vestibular surface is smooth.

The structure of the hymen is similar to that of the mucous membrane of the vagina.

Various views are held with reference to the origin of the hymen: thus it has been described as being derived (1) from the vaginal wall, (2) from the urogenital sinus, and (3) from both these: the upper layer of the fold being vaginal, and the lower urogenital (pudendal). For a full discussion and the literature of this question, see Berry Hart, 'A Preliminary Note on the Development of the Clitoris, Vagina, and Hymen,' *Jour. Anat. and Phys.*, vol. xxxi., 1896; F. J. Taussig, 'The Development of the Hymen,' *Amer. Jour. Anat.*, vol. viii., 1908; and G. Geilhorn, 'Anatomy, Pathology, and Development of the Hymen,' *Amer. Jour. Obst.*, vol. l.

URETHRA MULIEBRIS.

The female urethra (*urethra muliebris*) extends from the bladder downwards and forwards, in front of, and parallel to, the lower half of the vagina, and ends below by opening on to the roof of the pudendal cleft as the *orificium urethræ externum*. It is about 4 cm. in length, and, except during micturition, is closed by the apposition of its walls. The shape of its lumen on transverse section varies at different levels, and is also affected by the degree of contraction of its muscular wall. Near the upper end, the shape is usually crescentic, with the convexity forwards, owing to a prominence on the posterior wall, which extends downwards from the vesical orifice, and is known as the *crista urethralis*. About the middle, it may appear as a transverse slit about 6 mm. in breadth, or may exhibit a distinctly stellate form. Near its lower end, it forms a vertical slit, and its orifice has the same appearance, with distinct lateral lips. The mucous membrane, along the whole extent of the urethra, is thrown into fine longitudinal folds, which are obliterated on distension. The tube can be distended to admit a speculum 14 mm. in diameter without causing permanent incontinence.

The vesical orifice is generally situated about 1 cm. below a horizontal line prolonged backwards from the top of the pubic symphysis, and 4 cm. to 6 cm. behind the upper border of this joint, being pushed forwards (and also upwards) during the

[1] C. J. Cullingworth, 'Note on the Anatomy of the Hymen and that of the Posterior Commissure of the Vulva,' *Jour. Anat. and Phys.*, vol. xxvii., 1893.

distension of the rectum. As the pubic symphysis inclines downwards and backwards, and the urethra downwards and forwards, they tend to approach one another, and the urethra is often only about 1 cm. behind the lower part of the symphysis. The orifice is usually placed from 1 cm. to 2 cm. below the lower edge of the symphysis.

Structure and relations of the urethral wall.—The urethra has a firm tough wall about 6 mm. in thickness, which blends posteriorly with the anterior vaginal wall to form a urethro-vaginal septum, while in front it is separated from the pubes by fascia, fat, and a plexus of veins. A strong layer of fascia passes from the lower part of the posterior surface of the symphysis and adjacent portions of the pubic bones, backwards to the upper part of the urethral wall, forming on each side the anterior true ligament of the bladder. The pars intermedia of the clitoris lies anterior to the lower end of the urethra. On each side of the urethra is a plexus of veins, and near its external orifice these are replaced by the vestibular bulb. The pubic part of the levator ani passes backwards, lateral to the urethral wall, a little below its middle, but separated from it by fascia and veins (see fig. 267).

The wall of the urethra consists of a mucous, a submucous, and a muscular coat. The mucous membrane is white and covered with a stratified squamous epithelium, except near the bladder, where it is transitional. It contains a number of small recesses or lacunæ, and also numerous small acinous glands, which are homologous with the glands of the prostate. The ducts of two of the glands pass downwards, and open on the posterior part of the external orifice ; they are known as the *ductus para-urethrales*, or Skene's tubes.[1] The loose submucous coat contains a cavernous venous network. The muscular coat consists of an inner longitudinal and an outer circular layer of non-striped fibres, and some striped fibres, which extend along nearly the whole length of the anterior wall, but are only found towards the upper part of the posterior wall.

The **vessels** and **nerves** of the female urethra are very numerous, and are derived from the same sources as those of the vagina.

The female urethra is usually considered to correspond to that part of the male urethra which extends from the vesical orifice to the openings of the utricle and ejaculatory ducts into the prostatic portion. Evatt[2] found in a three-and-a-half months' female fetus, that glands, corresponding to those of the prostate at the same age, extended along the whole length of the female urethra, and the coalesced Müllerian ducts and the Wolffian ducts entered the middle part of the urethra. He, therefore, holds that the female urethra is homologous with the whole of the prostatic portion of the male urethra.

PARTES GENITALES EXTERNÆ.

The **pudendum**, or **vulva**, is a general term for the female *partes genitales externæ*. It includes the mons pubis, the labia majora and minora, certain masses of erectile tissue forming the clitoris, the vestibular bulbs, and the small and large vestibular glands—all of which lie in relation with a deep median pudendal cleft, or sinus urogenitalis. The superficial part of the external genitals forms a keel-shaped prominence situated in front of the pubic symphysis, and extending backwards into the anterior part of the perineum. The prominence is about 6 cm. or 7 cm. broad in front, and narrows to about 3 cm. behind. It is separated on each side from the median aspect of the thigh by a deep groove (*sulcus femorogenitalis*), which, in front, gradually becomes shallow as it turns outwards towards the inguinal ligament and,

[1] 'The Anatomy and Pathology of Two Important Glands of the Female Urethra,' *American Journal of Obstetrics*, vol. xiii., April 1880.
[2] *Op. cit.*, p. 294.

behind, curves outwards to become continuous with the gluteal fold. This genital eminence is formed by the mons pubis and the two labia majora, between which is the rima pudendi (see fig. 271).

The **mons pubis** (*mons Veneris*) is an eminence situated in front of the pubic symphysis, and formed by a mass of areolar and adipose tissue covered by skin provided with numerous hairs. It is continuous above with the anterior abdominal wall, the junction of the two being usually marked by the cessation of the pubic hair. Below, in passes into the two labia majora, and is described as forming their anterior commissure.

FIG. 271.—VIEW OF THE EXTERNAL GENITALS OF ADULT FEMALE. (J. Symington.)

1, right labium majus; 2, mons pubis; 3, right natis.

The **labia majora** (*labia majores pudendi*) are two rounded folds of skin, extending downwards and backwards from the mons to within 2 cm. or 3 cm. of the anus, and separated from one another by the rima pudenda. Each labium has an outer convex surface resembling ordinary skin, covered with hairs, and an inner smooth surface of a pinkish colour, which lies against the opposite labium. Within the substance of the fold, there is found—besides fat, vessels, nerves, and glands—a tissue resembling that of the dartos in the scrotum of the male, to which the labia majora correspond. The labia majora, by their contact, generally conceal the other parts of the external genitals; not infrequently, however, in old persons, the labia minora project forwards between the labia majora, so as to be visible externally. They are usually described as uniting in front and behind to form an anterior and a posterior commissure; but the prominences they form, as a rule, gradually disappear posteriorly, and do not turn inwards to form a distinct transverse fold.

The **labia minora**, or **nymphæ**, are two narrow pendulous folds of skin, one on the inner surface of each labium majus. From their attached borders, they extend downwards, having their outer surfaces in contact with the labia majora, and their inner surfaces against one another. Anteriorly, each labium divides into two branches: the upper of which joins the prepuce of the clitoris, and the other its glans. Posteriorly, the labium minus may end by gradually blending with the inner surface of the labium majus, but in some cases it can be traced backwards, until it becomes continuous with a transverse fold of skin, situated at the anterior edge of the perineum, and known as the *fourchette*, or *frenulum labiorum pudendi*. The nymphæ and fourchette resemble one another, and differ from the labia majora in being devoid of fat.

In young subjects, the labia minora are of a rose-red colour, and look like a mucous membrane; but as age advances, they become darker in colour and more like skin.

It is held by some that the labia majora turn inwards, posteriorly, to form a transverse fold of skin, which is sometimes regarded as forming the fourchette, or as independent of it. Luschka (*Das Becken*, 1864, fig. lx.) was apparently the first anatomist to direct attention to the fact that the labia minora were occasionally prolonged backwards to join the fourchette. Ballantyne ('The Labia majora and Hymen,' *Edinburgh Med. Jour.*, 1888), Cullingworth ('A Note on the Anatomy of the Hymen and of the Posterior Commissure of the Vulva,' *Jour. Anat. and Phys.*, vol. xxvii., 1893), and Blacker ('Some Observations on the Topographical Anatomy of the Fourchette,' *Jour. Anat. and Phys.*, vol. xxx., 1896) agree—mainly as the result of clinical observations—that the fourchette ought to be considered as the posterior part of the labia minora. The presence of a posterior commissure uniting the labia majora is very rare, and it is certainly incorrect to represent, as some have done, the fossa navicularis as being situated between the posterior commissure and the fourchette.

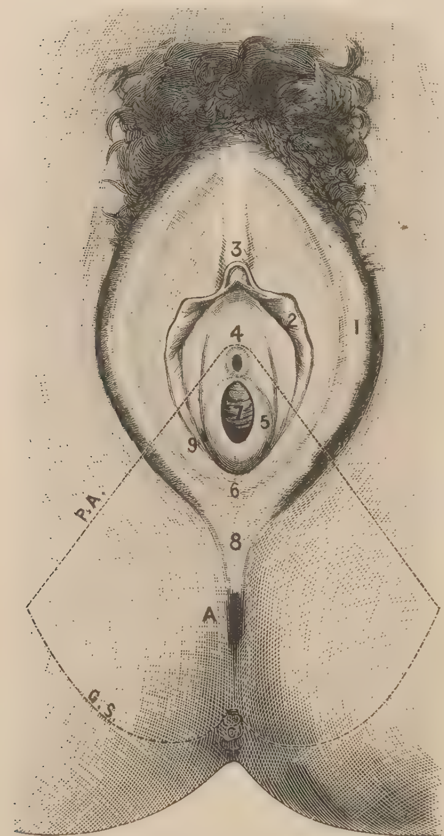


FIG. 272.—VIEW OF EXTERNAL GENITALS OF ADULT FEMALE, WITH THIGHS ABDUCTED, AND LABIA MAJORA AND MINORA SEPARATED. (J. Symington.)

1, labium majus; 2, labium minus; 3, preputium clitoridis; 4, vestibule; 5, hymen; 6, fourchette; 7, vaginal orifice; 8, base of perineal body; 9, opening of duct of gland of Bartholin; A., anus. Dotted line to show position of outlet of ligamentous pelvis; G.S., great sacro-sciatic ligament; P.A., pubic arch; C., coccyx.

Erectile tissue.—All the parts of the vulva are abundantly supplied with blood-vessels; and in certain situations there are masses composed of venous plexuses, or erectile tissue, corresponding to those forming the penis in the male. These masses are the corpora cavernosa and glans of the clitoris, the pars intermedia, and the vestibular bulbs.

The **clitoris**, the homologue of the penis, is an erectile organ composed of two corpora cavernosa, a glans, and a pars-intermedia. The corpora cavernosa are separated behind, where they constitute the crura of the clitoris, but they unite in front to form its body. Each crus is firmly attached to the inner aspect of the pubic arch, superficial to the fascia inferior, and is covered by the ischio-cavernosus, or erector clitoridis muscle. In the body of the clitoris, the two corpora cavernosa are closely united by their flattened inner surfaces, the fibrous septum between them (*septum pectiniforme*) being incomplete. The body is fixed by a small suspensory ligament to the front of the symphysis pubis, from which point it extends forwards for about 2 cm., and then turns sharply downwards and backwards to end in a depression at the base of the glans. The glans is composed of spongy erectile tissue which forms the extremity of the clitoris and, as in the male,

possesses a free surface ending at its base in a corona. This free surface is imperforate, highly sensitive, and surrounded superiorly by a membraneous fold—like the prepuce of the penis—while below, it gives attachment to a small frænum. The prepuce and frænum are continuous with the labia minora.

The pars intermedia is a slender elongated mass of erectile tissue, which passes backwards from the glans nearly to the external orifice of the urethra, where it

FIG. 273.—TRANSVERSE SECTION, PASSING FROM ABOVE DOWNWARDS AND SLIGHTLY BACKWARDS, THROUGH THE ANTERIOR PART OF THE PELVIS OF A WOMAN AGED FIFTY-FOUR YEARS, SEEN FROM THE FRONT. Natural size. (J. Symington.)

B, bladder, cut across about half an inch in front of urethral orifice, 1; E, external orifice of urethra forms a vertical slit on a slight prominence; A, opening of left ureter; V.C., pudendal cleft; U, anterior wall of urethra; V.B., vestibular bulb; C, crus clitoridis; B.C., bulbo-cavernosus muscle; I.C., ischio-cavernosus muscle; L.M., labium majus; L.MI., labium minus; P.A., pubic arch; O.I., obturator internus muscle; X., on fascia inferior diaphragmatis urogenitalis.

separates into two lateral portions, which become continuous with the vestibular bulbs. It lies just below the body of the clitoris and in the roof of the pudendal cleft. The clitoris differs from the penis in being much smaller and in not being traversed by a urethra. In consequence of its small size, it is concealed within the pudendal cleft, and the upper and lateral surfaces of its body are usually embedded in the fat of the lower part of the mons pubis. If the clitoris be somewhat enlarged, or the fat of the mons pubis small in amount, the dorsal surface of the anterior part of the body of the clitoris forms a prominence called the torus clitoridis.

The vestibular bulbs are two oval masses of erectile tissue about 3 cm. long and 1·5 cm. broad, which are continuous in front with the pars intermedia, and pass backwards and outwards lateral to the lower ends of the vagina, urethra, and the adjacent portion of the pudendal cleft. Each bulb is covered on its lateral aspect by the corresponding bulbo-cavernosus muscle, which separates it from the pubic arch.

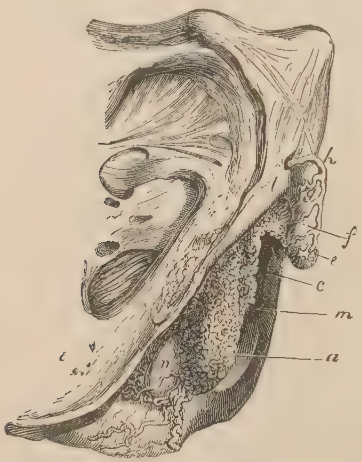


Fig. 274.—Lateral view of the erectile structures of the external organs in the female. (From Kobelt.)

The blood-vessels have been injected, and the skin and mucous membrane have been removed; *a*, bulbus vestibuli; *c*, plexus of veins named pars intermedia; *e*, glans clitoridis; *f*, body of the clitoris; *h*, dorsal vein; *l*, right crus clitoridis; *m*, vestibule; *n*, right glandula vestibularis major.

The **urogenital space**, or **pudendal cleft**, is a median fissure, which opens below on to the surface between the two labia majora, and receives at its upper part the orifices of the urethra and vagina. The superficial part of this cleft is bounded by the inner surfaces of the two labia majora and the rima pudenda, which lies between them; is limited in front by the anterior commissure, but, behind, passes over the perineal body to become continuous with the cleft between the buttocks. Deep to this part of the cleft are the glans clitoridis, with its prepuce and frænum, the labia minora, and fourchette. Between these structures and the orifices of the urethra and vagina is the vestibule: the part just below the vaginal orifice being often called the vestibulum vaginæ, and the recess between the hymen and the fourchette the fossa navicularis. The more superficial part of the space, bounded by the labia majora and minora, is lined by skin, and the deeper part by mucous

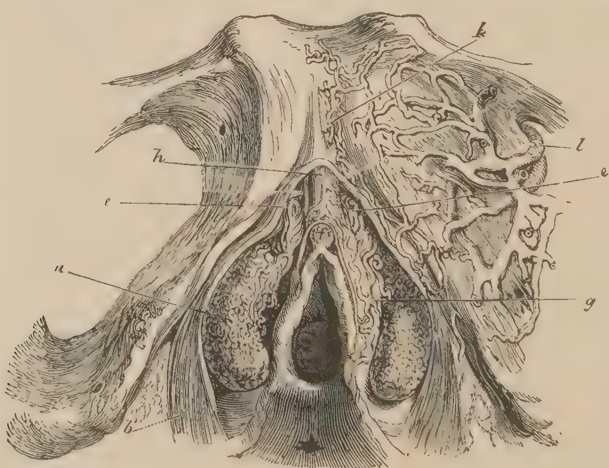


Fig. 275.—Front view of the erectile structures of the external organs in the female. (From Kobelt.)

a, bulbus vestibuli; *b*, bulbo-cavernosus muscle; *e*, *e*, venous plexus or pars intermedia; *f*, glans clitoridis; *g*, connecting veins; *h*, dorsal vein of the clitoris; *k*, veins passing beneath the pubes; *l*, the obturator vein.

membrane, which is continuous with the mucous membrane of the urethra and vagina. According to Berry Hart, the line separating skin from mucous

membrane runs from just below the prepuce of the clitoris, backwards, on each side along the base of the inner aspect of the labium minus, to the outer aspect of the base of the hymen. The mucous membrane is smooth, reddish in colour; is covered by a scaly epithelium, and is provided with a considerable number of mucous crypts or follicles, and with glands (*glandulæ vestibularis minores*), which secrete an unctuous and odorous substance. Sebaceous glands are found beneath the prepuce and upon the labia majora and minora. Fine, downy hairs can be seen on the inner aspect of the labia majora, but none on the labia minora.

The **glandulæ vestibularis majores** (Bartholin's or Duverney's glands, fig. 274, *n*), corresponding to Cowper's glands in the male, are two reddish-yellow, round or oval bodies, measuring about 10 mm. to 12 mm. in the longest diameter, and situated at the posterior end of the vestibular bulbs. Sometimes some of their lobules project into the bulbs, and they may be broken up into several lobes by bundles of fibrous and muscular tissue. Their ducts, which are long and simple, open one on each side, a little in front of the fossa navicularis, by the side of the vaginal orifice, in the groove between the attached border of the hymen and the labium minus (Cullingworth). As a rule, the orifices of these ducts can be distinctly recognised with the naked eye.

Blood-vessels, lymphatics, and nerves.—Arteries.—The external genitals are supplied almost entirely by branches of the internal pudendal arteries, but some small branches go to the labia majora from the external pudendal and anterior labial branches of the femoral arteries. The erectile tissue receives on each side an artery to the vestibular bulb, and a deep and a dorsal branch to the clitoris from the internal pudendal. The venous blood is returned through the pudendal, vesical, and vaginal plexuses to the hypogastric vein, and by the anterior labial and external pudendal veins into the femoral vein. Most of the lymphatic vessels from the external genitals pass to the superficial inguinal glands, but some go to the glands on the side wall of the pelvis. The sensory nerves to the skin and mucous membrane of the external genitals are mainly derived from branches of the pudendal nerves (second, third, and fourth sacral); the second sacral probably supplying the clitoris, the third the posterior part of the labia majora, and the fourth the perineum. The skin of the mons pubis, and the anterior part of the labia majora, get their nerve-supply from the first and second lumbar nerves, through the ilio-inguinal and genito-femoral nerves. The muscles of the external genitals are supplied by the pudendal nerves, while the blood-vessels going to the erectile tissue are accompanied by vaso-motor fibres of the sympathetic.

Varieties.– The external genitals in the female may exhibit a more or less marked tendency to resemble those of the male, giving rise to the condition known as *pseudo-hermaphroditismus femininus*. The clitoris is large and prominent, and the external opening of the urogenital sinus is small, while the ovaries may have descended into the labia majora. Duplicity of the female genitals is usually limited to the uterus and vagina, but in rare cases may also involve the external genitals (see Gemmell and Paterson, 'Duplication of Bladder, Uterus, Vagina, and Vulva, with Successive Full-time Pregnancy and Labour in each Uterus,' *Journal of Obstetrics and Gynæcology of the British Empire*, January 1913). A form of epispadias is met with in the female as a very rare abnormality. In epispadias the clitoris and its prepuce are divided, and the urethral opening is found between the two halves.

MAMMÆ.

The mammary glands (*mammæ*), which yield the milk in the female, are functionally accessory parts to the reproductive system, while from their position and development they are anatomically appendages of the integumentary system. They give a name to a large class of vertebrate animals (Mammalia), which are

distinguished by the possession of these organs. In the human subject, as in Primates generally, these glands consist of one pair, which are pectoral in position.

Shape and position.—When fully developed in the human female, they form, together with the integuments and a considerable quantity of fat, two uneven hemispherical or conical eminences (the breasts), placed one at each side on the antero-lateral aspect of the thorax (fig. 277). A little below the centre of each breast, on a level with the fourth rib, or slightly lower, projects a small cylindrical or conical body, named the nipple (*papilla mammæ*), which points forwards and outwards, and often somewhat upwards.

Each gland is situated in the superficial fascia, and extends, in a vertical line passing through its nipple, from the second to the sixth or seventh rib, and in a

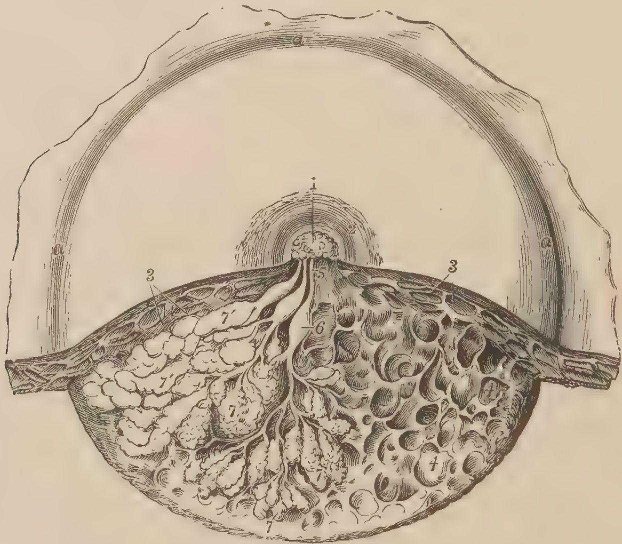


FIG. 276.—DISSECTION OF THE LOWER HALF OF THE FEMALE MAMMA DURING THE PERIOD OF LACTATION. Two-thirds natural size. (Luschka.)

a, a, a, undissected part of the mamma; 1, papilla mammæ; 2, areola; 3, subcutaneous masses of fat; 4, loculi in the connective tissue which supports the glandular substance; 5, three lactiferous ducts passing towards the nipple where they open; 6, one of the sinuses or ampullæ; 7, some of the glandular lobules which have been unravelled; 7′, others massed together.

horizontal line, through the same structure, from a little external to the lateral border of the sternum, opposite the third intercostal space, to the fourth intercostal space, somewhat in front of the mid-axillary line. The gland measures about 10 cm. to 12 cm. from above downwards, a little more across, and about 3 cm. to 4 cm. in thickness opposite its most prominent part.

The average weight of each gland in the virgin is from 150 grms. to 200 grms.; in the nursing woman from 400 grms. to 500 grms. (Testut).

In the adult nullipara, the superficial or cutaneous surface of the gland is convex, but uneven, owing to the presence of numerous irregular processes passing towards the skin, with which some of them are united by bands of connective tissue—the so-called ligaments of Astley Cooper.[1] Lobules of fat occupy the intervals between these processes. This surface looks forwards and outwards. The posterior or deep surface of the gland is smooth and concave, and lies in close contact with the deep fascia with which it is connected by loose cellular tissue generally devoid

[1] *On the Anatomy of the Breast*, London, 1840.

of fat. The upper and median portion of this surface, comprising about two-thirds of its whole extent, lies upon the pectoralis major; external to this muscle, the posterior surface rests on the axillary fascia, which separates it from the serratus anterior, and, lower down, it is in relation with the digitations of the serratus anterior and external oblique, which arise from the fifth and sixth ribs.[1] The median half or so of the circumference of the gland is thin and not sharply defined, but breaks up into numerous irregular processes, which branch and unite to form a reticular

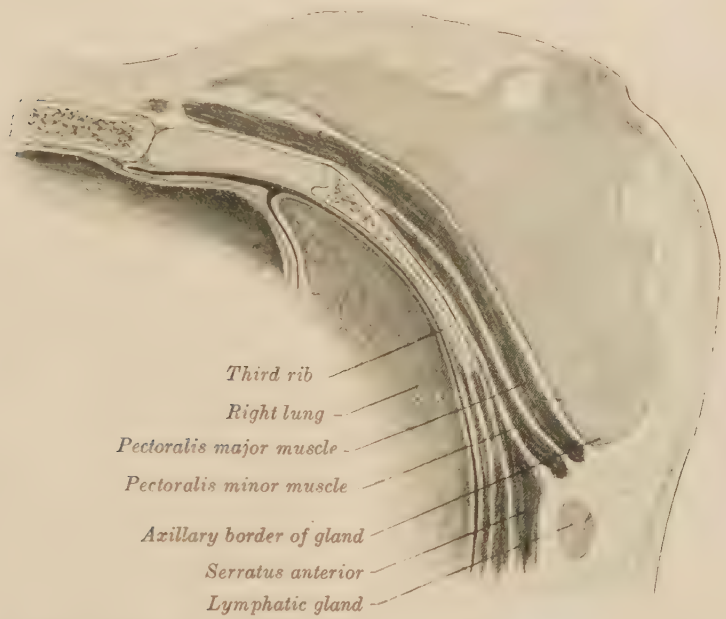


FIG. 277.—FROM A HORIZONTAL SECTION OF THE THORAX OF A GIRL, AGED FOURTEEN YEARS, SHOWING THE RIGHT MAMMARY GLAND DIVIDED AT THE LEVEL OF THE NIPPLE. Two-thirds natural size. (J. Symington.)

The patient died of pericarditis, and the pericardial effusion had displaced the right lung laterally.

formation enclosing lobules of fat. The stroma of the peripheral processes, where the gland tissue ceases, becomes directly continuous with the connective-tissue framework of the adjacent fat lobules.

The lateral half, on the other hand, is thick and rounded, and separated from the adjacent fat by a well-marked layer of fibrous tissue (fig. 277). Occasionally, small processes of the gland penetrate the deep fascia, and are found embedded in the subjacent muscular tissue.

Structure of the papilla mammæ or **nipple.**—The surface of the nipple is dark, and around it there is a coloured circle or *areola mammæ*, within which the skin is also of a darker tinge than elsewhere. In the virgin, these parts are of a rosy pink colour, differing somewhat according to the complexion of the individual, but they are always darker in women who have borne children. Even in the second month of the first pregnancy, the areola begins to enlarge and acquires a darker tinge; these changes go on increasing as gestation advances, and are regarded as signs to be relied on in judging of suspected pregnancy. After lactation is over, the dark colour subsides, but never entirely disappears. The skin of the

[1] H. J. Stiles, 'The Surgical Anatomy of the Breast and Axillary Lymphatic Glands,' *Edinburgh Medical Journal*, 1882.

Fig. 278.—Horizontal section of the mammary gland at the level of the nipple in a nulliparous female, aged twenty-seven years. Natural size. (Stiles.)

The specimen was kept for two days in a 5 per cent. solution of nitric acid, then washed in water and preserved in methylated spirit.

N, nipple; S, skin; L.C, ligament of Cooper connecting a process of the gland with the skin; P.P, peripheral processes; F.L, fat lobules; P.M, pectoralis major muscle.

nipple is marked with many wrinkles, and is covered with papillæ; besides this, it is perforated at the tip by about twenty foramina, which are the openings of the lactiferous ducts; and near its base, as well as upon the surface of the areola, there are scattered rounded elevations, which are caused by the presence of well-marked sebaceous glands with branched ducts—four or five of which open on each elevation. The sudoriferous glands of the areola are also large and much convoluted, but there are no sudoriferous glands in the nipple proper, nor are there any hair follicles. The tissue of the nipple contains a large number of vessels, together with much plain muscular tissue, and its papillæ are highly sensitive; it becomes firmer and more projecting from mechanical excitement—a change caused by contraction of the muscular fibres, which form concentric circles round the base of the nipple, and radiating bands running from base to apex. There is a quantity of plain muscular tissue in the subcutaneous tissue of the areola.

Structure of the mamma.—The mamma is composed of glandular tissue, supported by a connective-tissue stroma, in which the blood-vessels, lymphatics, and nerves ramify. It also comprises a greater or less amount of adipose tissue. The relative amount and distribution of these constituents varies considerably according to the age of the individual, and whether the gland is, has been, or has not been, functionally active. In the adult nullipara, the gland is usually a firm, conical mass, with its apex at the nipple. This part is called the corpus mammæ; from it, peripheral processes extend in various directions. Under the nipple and areola, the stroma is entirely devoid of fat, but towards the circumference a few fat lobules may be embedded in it. The stroma of the peripheral processes, where the gland tissue ceases, becomes directly continuous with the connective-tissue

framework of the adjacent fat lobules. At puberty, the gland appears, on external examination, to be well developed; but it really consists mainly of stroma and excretory ducts—the true secreting acini being few in number. During pregnancy and lactation, the gland tissue proper undergoes a marked development, and the stroma is relatively reduced in amount, so that on section the gland presents to the naked eye a close resemblance to a salivary gland. After the period of functional activity is ended, the gland returns by a process of involution to its resting-stage, but it does not regain the appearances it exhibited before pregnancy. Thus the main compact mass of the gland or corpus mammæ is less distinct, and its stroma is looser and contains numerous fat lobules, while the peripheral processes are larger and have a more extensive distribution. A layer of fat of greater or less thickness is now usually found between the gland and the deep fascia.

After the menopause, the appearance of the gland varies according to the general condition of the subject. Thus in thin women it forms a somewhat flattened disk, which comes into close relation both with the skin and the subjacent muscles; while in obese women, the mamma is composed mainly of fat, the stroma investing the parenchyma forming a wide open meshwork, except in the immediate vicinity of the nipple.

The glandular substance of the mamma consists of numerous distinct lobes (*lobi mammæ*), which may be as many as twenty in number, held together by firm intervening fibrous or areolar tissue, and having adipose tissue penetrating between them. Each

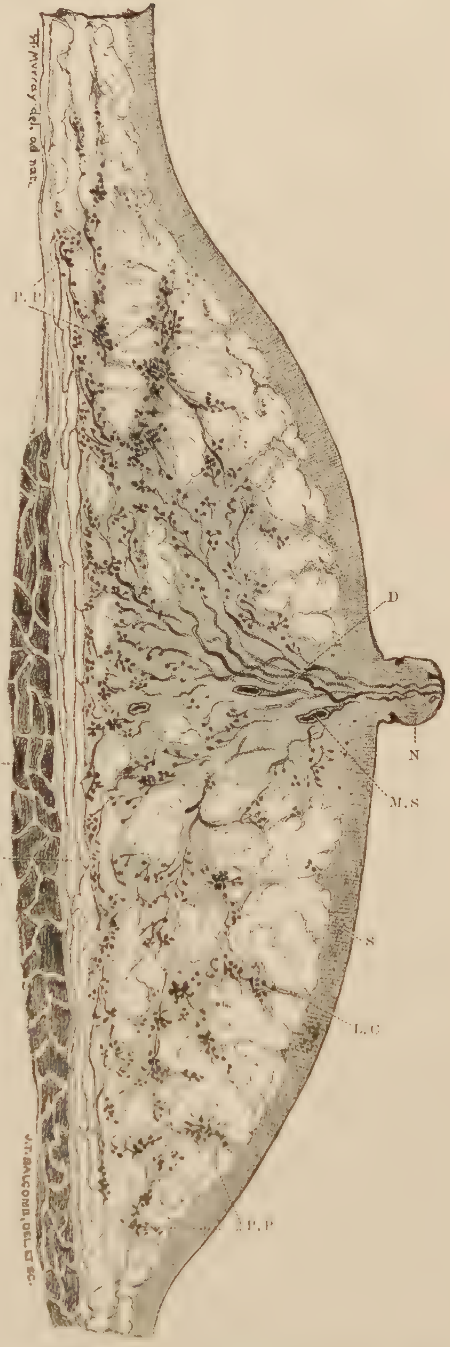


Fig. 279.—Horizontal section of the mammary gland at the level of the nipple in a multiparous female, aged forty years. Natural size. (Stiles.)

The specimen was treated in the same way as that shown in fig. 278.

M.S, sinus or ampulla of milk-duct; R.M.F, retro-mammary fat; other letters as in fig. 278.

x 2

of these lobes is provided with an excretory duct, and is subdivided into smaller lobes, and these again into the lobules (*lobuli mammæ*), which are beset with the alveoli. Each lobe is practically a distinct gland, although the lobes come into close contact with one another. Sometimes, besides the principal lobes, small accessory lobes or glands are met with near the base of the nipple. The lobules are separated from one another in the human subject by a large quantity of areolar tissue (fig. 281). The interlobular tissue contains numerous plasma-cells. The substance of the lobules is of a pale reddish cream-colour, contrasting with the adjacent fat, and is rather firm. The excretory ducts, named the *lactiferous ducts*, are, like the lobes, about twenty in number; they converge towards the areola beneath which they become considerably dilated, especially during lactation, so as

FIG. 280.—TRANSVERSE SECTION OF THE NIPPLE. (Testut, after de Sinéty.)

a, sections of lactiferous ducts, with (*e*) columnar epithelium; *b*, connective tissue; *m*, *m′*, plain muscular fibres, cut longitudinally and transversely respectively; *v*, blood-vessels.

to form *ampullæ* or *sinus lactiferi*, about 12 mm. long and 6 mm. wide (fig. 276), which serve as small temporary reservoirs for the milk. At the base of the nipple, all these ducts, again reduced in size, are assembled together—those in the centre being the largest—and then proceed, side by side, surrounded by areolar tissue and vessels, and without communicating with each other, to the summit of the nipple, where they open by separate orifices; these orifices are seated in little depressions, and are smaller than the ducts. The walls of the ducts are composed of areolar tissue, with longitudinal and circular elastic fibres, but without muscular tissue, and are lined by a single layer of columnar cells, except near their orifices, where the epithelium is squamous and stratified. In the virgin, the alveoli are occupied by polyhedral cells, but during lactation they are distended, and have large lumina, which, like the ducts, are filled with milk. After lactation is over, the glandular tissue undergoes involution, but still remains more abundant than in the virgin condition. The breasts tend to become relaxed and pendulous by frequent

lactation, especially in warm climates. The skin over the breasts beyond the areola is smooth and usually very white.

In the adult male, the mammary gland and all its parts exist, but quite in a rudimentary state, the gland itself measuring only from 15 mm. to 20 mm. across, and about 4 mm. thick. Occasionally, the male mamma—especially in young subjects—enlarges and gives out a thin watery fluid; and, in rare cases, it has secreted milk.

Blood-vessels, lymphatics, and nerves.—The **arteries** which supply the mammary glands are the external mammary and some other branches of the axillary artery, the *internal mammary* from the subclavian, and the subjacent *intercostals.*

The arteries end in a rich network of capillaries around the alveoli and in cavernous or erectile tissue in the nipple. The **veins** generally correspond to

FIG. 281.—SECTION OF MAMMARY GLAND OF FEMALE DURING LACTATION. (Testut, after de Sinéty.) *a*, lobule of gland; *b*, acini lined by cubical epithelium; *c*, duct; *t*, connective-tissue stroma.

the arteries, but those on the surface of the gland are not usually accompanied by arteries. The **lymphatics** within the mammary gland form plexuses in the connective tissue around the alveoli and ducts. There are also lymphatics, which accompany the blood-vessels in the gland, and, as elsewhere, the smaller blood-vessels have usually a single accompanying lymphatic vessel of much larger calibre than the artery itself, while the sheaths of the larger vessels contain two or three lymphatics (Stiles). These perivascular lymphatics communicate freely with those around the lobules and ducts of the gland. In addition to the intramammary lymphatics, there are four other sets of vessels connected with the mammary lymphatic system: namely—*cutaneous*, *subareolar* of Sappey, *circum-mammary*, and *retro-mammary*. The lymphatics from the inner part of the gland pass with the perforating branches of the internal mammary artery to join the small sternal glands situated along the course of this vessel. On the outer side of the gland the vessels are much larger, and unite to form two or three principal trunks which pass to lymphatic glands in the axilla. The **nerves** proceed from the anterior and lateral *intercostal* cutaneous branches. They pass partly to the glandular substance and blood-vessels, partly to the skin. In the nipple, many of them

end in tactile corpuscles within the papillæ, and some of those in or near the areola enter Pacinian corpuscles.

Development of the mammary gland.—The first rudiment of the mammary gland appears as a thickening (milk-line or ridge) of the epithelium on the ventro-lateral aspect of each side of the trunk between the fore- and hind-limbs. This thickening was described and figured in a human embryo about 15 mm. long, by Kallius ('Ein Fall von Milchleiste bei einem menschlichen Embryo,' *Anat. Hefte*, Heft 24, 1898), and it has since been observed in still younger embryos: for instance, by C. Elza (*Anat. Hefte*, Heft 106), in one 9·5 mm. long. The thickening grows downwards and spreads laterally, so as to form a lens-shaped mass, which soon becomes sunk below the general surface. From this common invagination, there are special outgrowths of the epithelium into the corium—one for each lobe of the future gland. These outgrowths, as in other racemose glands, become branched, and their branches end in enlargements.

The formation of these sprouts goes on until birth; but the development of glandular alveoli from them does not occur until the approach of puberty, in the female, and in the male not at all. The projection of the nipple from the rest of the mammary area does not begin until about the first year after birth; within it, a large amount of plain muscular tissue becomes formed. The remainder of the mammary area becomes the areola. As the nipple grows, it carries the ducts of the various lobes of the gland with it, so that they open on the surface by separate orifices.

The subsequent growth of the gland is comparatively tardy. At the third or fourth year of infancy, there is little or no difference in male and female children. The fuller development of the gland in the female occurs only towards puberty. It is probable that during the later period of pregnancy, not only do the alveoli increase in size, but new alveoli may bud laterally from the pre-existing ones, and that after lactation some of the alveoli may become atrophied and disappear.

Morphology.—The mammary glands are generally considered to belong to the type of sudoriferous glands—both arising as divergent forms of a primitive tubular gland. Sebaceous glands have been observed opening into the ducts of mammary glands, and from this fact it has been suggested by some that the mammary glands are modified sebaceous glands. In Echidna, and in the Marsupialia, hair follicles, sebaceous glands, and mammary glands are formed as sprouts from the primary epithelial downgrowth, but the hair follicles and their associated sebaceous glands tend to atrophy and disappear. Eggeling ('Ueber ein wichtiges Stadium in der Entwickelung der menschlichen Milchdrüse,' *Anat. Anzeig.*, Bd. xxiv., 1904) has recorded an example of a somewhat similar condition in a human embryo. The occasional association of mammary and sebaceous ducts is apparently due to the atrophy of the hair follicles. Gegenbaur considered that the mammary organs had a diphyletic origin: the milk glands of Ornithorhynchus and Echidna being modified sweat-glands, and those of all the higher mammals sebaceous glands; but a more extended knowledge of the development of the mammary glands in different mammalian groups would appear to demonstrate the fact that they all belong to the same type. In the Ornithorhynchus, and probably also in the Echidna, there are no teats, and the secretion is discharged on to a flat surface by a number of separate openings. In the human subject, the ducts terminate separately at the summit of the nipple; while in the majority of placental mammals, they open at the base of the nipple into a common duct, by which the milk is conveyed through the nipple on to the surface. The number and position of the teats vary considerably, ranging from one to ten or eleven pairs, and being pectoral in some mammals, inguinal in others; while in many they extend along the whole length of the ventral surface of the trunk.

Varieties.—Entire absence of both glands and nipples is very rare; a few such instances, however, are recorded in otherwise normally developed individuals. Thus W. Wylie ('Case of Entire Absence of both Mammæ in a Female, aged Twenty-one Years,' *Brit. Med. Jour.*, 1888, vol. xi., p. 235) has recorded this condition. A small mole existed where the right nipple is normally situated. In another case, reported by Batchelor ('Absence of Mammæ in a Woman,' *Brit. Med. Jour.*, 1888, vol. xi., p. 876), the usual position of each nipple was occupied by a small area of pigmented skin. It may be associated with absence of hair and an atrophic condition of the other integumentary appendages. Absence of one mammary gland is almost as uncommon as that of both, and is usually associated with an imperfect development of the thoracic wall on the same side. The glands themselves may be well formed, but the nipples absent. Such cases are of interest developmentally, as the papillary elevation of the skin giving rise to the nipple is secondary to the epithelial downgrowth from which the gland itself is formed.

It was shown by O. Schultze ('Ueber die erste Anlage des Milchdrüsenapparates,' *Anat. Anzeig.*, Bd. vii., s. 265) that in the embryo of various mammals—such as the cat, rabbit, and

mole—a line of thickened epithelium is formed on each side of the trunk, extending from the axilla downwards and inwards to the groin. It is at intervals along this line that the mammary glands are developed in polymastic mammals; and in the great majority of additional glands in the human subject they are found in a corresponding position, and may be designated axillary, pectoral, abdominal, inguinal, or pudendal mammæ. The supernumerary mammary structures are usually represented by the nipple only (polythely); but in some cases the glandular tissue is well developed and may be functionally active (polymasty). Most of the cases of additional mammæ appear, on one or both sides, just below and internal to the normal pair. The largest number of additional glands that has hitherto been recorded is eight. In this instance, which was described by Neugebauer ('Eine bisher einzig dastehende Beobachtung von Polymastie mit 10 Brustwarzen,' *Centralbl. f. Gynäkologie*, 1886), in a woman aged twenty-three, there were three pairs of nipples above the normal ones, and one pair below. It is probable that in this case, as Roger Williams ('Polymastism,' *Jour. Anat. and Phys.*, vol. xxv., 1891) suggests, the two nipples below the normal pair did not represent a pair of glands, but single examples of two pairs, as the right one was some inches higher up than the left. If such be the case there were representatives of six pairs of glands in this woman. Ammon ('Einige Bemerkungen betreffend das Vorkommen der überzähligen Brustwarzen und die Richtung der Körperhaare auf der Brust,' *Mitgetheilt in R. Weidersheim: Der Bau des Menschen als Zeugniss für seine Vergangenheit*, 1893), has described a case of three additional pairs of nipples in a man aged twenty-two years. One pair was placed above the normal nipples on the anterior folds of the axillæ, another near the lower margin of the chest wall, and the lowest on the anterior wall of the abdomen above the level of the umbilicus. A number of cases of axillary mammæ with nipples have been recorded: sometimes, however, the sudoriferous glands of the axilla become enlarged during pregnancy and secrete milk (Champneys and Bowlby, 'Further Observations on the Development of Mammary Functions by the Skin of Lying-in Women,' *Medico-chirurgical Transactions of London*, vol. lxix., 1895). Less frequently, mammary glands have been observed on the mons pubis (Blum, 'Fall von supernumerärer Mamma im Bereich des behaarten Mons Veneris mit 7 Warzen,' *Münchener med. Wochensch.*, Bd. liv., 1907). Those supernumerary glands which appear along the milk-line may be regarded as of an atavistic nature. Supernumerary glands, however, may appear on other parts of the body (*mammæ erraticæ*) as over the acromion process, on the upper part of the thigh, or even on the back; such cases show the capacity of other cutaneous glands to take on a mammary function. (For a full discussion of the morphology and variations of the mammary glands consult Bonnet, 'Die Mammarorgane im Lichte der Ontogenie und Phylogenie,' *Ergebnisse der Anatomie und Entwickelungsgeschichte*, Bd. ii., 1893, and Bd. vii., 1898; and Bresslau, 'Der Mammarapparat,' *Ibid.*, Bd. xix., 1909.)

THE DUCTLESS GLANDS.

THE remaining organs to be described all belong to the class of bodies known as *ductless glands.* Some of these—such as the spleen and the lymphatic glands—are concerned in the formation of lymph. Others—such as the thyroid gland and the parathyroids, the thymus, the suprarenal glands and various paraganglia, and the pituitary body—are internally secreting glands. The microscopic structure of all these glands is described in Part I. of this volume. The general distribution of the lymphatic glands will be given in Vol. IV., and the naked-eye anatomy of the pituitary body is described in Vol. III., Part I. The macroscopic anatomy of the spleen, the thyroid and parathyroid, the thymus, the suprarenal glands, and the small paraganglia, will be noticed here.

LIEN.

The **lien** or **spleen** (figs. 282 to 285) is a soft, highly vascular contractile and very elastic organ of a dark purplish colour. It is placed obliquely behind the stomach, its upper and inner end being in the posterior part of the left epigastric region, the larger portion in the left hypochondriac region, while its lower extremity reaches into the left lumbar region (Addison). Its size varies considerably not merely in different individuals, but in the same person, according to its degree of vascularity; so that it is difficult to state what are its ordinary dimensions and weight. Its long axis, which is directed from above downwards, outwards, and somewhat forwards, nearly parallel to the posterior part of the lower ribs, measures about 12 cm., its breadth is 8 cm., and thickness 3 cm. to 4 cm. It lies opposite the ninth, tenth, and eleventh ribs, and extends from about the level of the upper border of the body of the eleventh thoracic vertebra to the upper border of the first lumbar. In the adult, it may vary in weight from 100 grms. to 300 grms., the average being about 170 grms. Its volume varies enormously, but usually does not exceed 200 c.c. to 300 c.c. After the age of forty, the average weight gradually diminishes. In intermittent, and some other fevers, the spleen is much enlarged, reaching below the ribs, and often weighing as much as 18 lb. to 20 lb. It is the largest of the ductless glands.

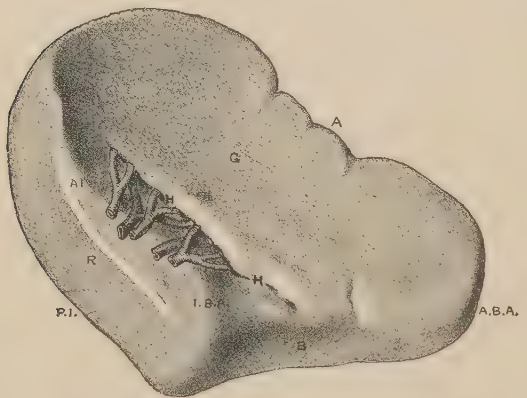


FIG. 282.—THE SPLEEN OF AN INFANT AGED FIVE DAYS, HARDENED *in situ* BY THE CHLORIDE OF ZINC METHOD. (Drawn from a model prepared by A. F. Dixon.)

G, gastric surface; R, renal surface; B, basal surface; A, anterior border; A.I, antero-internal or inner border; P.I, posterior or postero-internal border; I.B.A, internal basic angle; A.B.A, anterior basic angle; H, hilum.

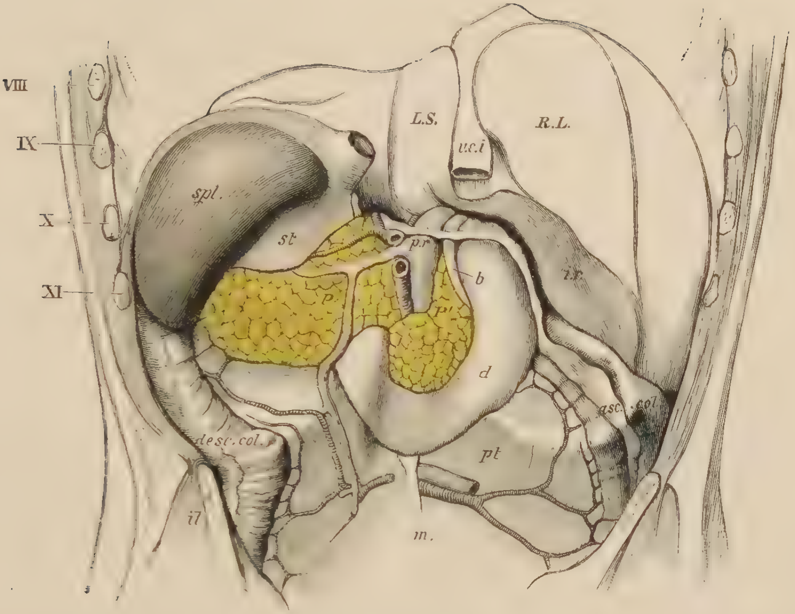


FIG. 283.—VIEW OF THE ABDOMINAL VISCERA FROM BEHIND, AFTER REMOVAL OF THE SPINAL COLUMN, THE WHOLE OF THE POSTERIOR WALL OF THE ABDOMEN, AND THE KIDNEYS AND SUPRARENAL GLANDS, THE PERITONEUM BEING LEFT. One-third natural size.

(This and the next figure are taken from Prof. His's models.)

P, pancreas; *P′*, its head; *d*, duodenum; *st*, stomach; *spl.*, spleen; *R.L.*, right lobe of the liver; *L.S.*, Spigelian lobe; *v.c.i*, vena cava inferior; *p.r*, portal vein; *b*, common bile-duct; *i.r*, impression for the right kidney on the posterior surface of the liver; the situation of the two kidneys is well shown by the corresponding impressions in the cast; *asc. col.*, *desc. col.*, ascending and descending colons; *pt.*, back of the peritoneum; *m*, line of attachment of the mesentery; VIII, IX, X, XI, the corresponding ribs; *il.*, ileum.

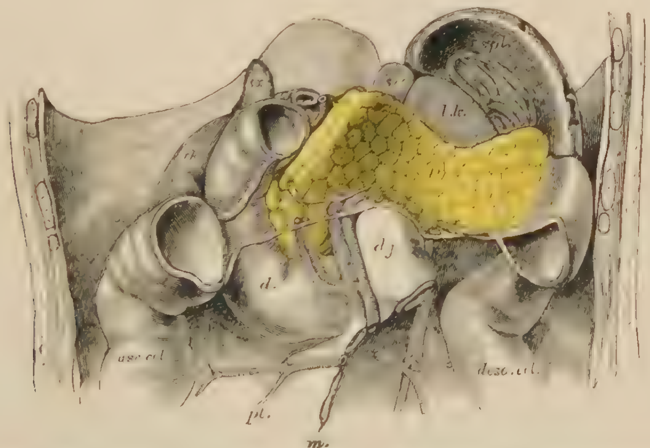


FIG. 284.—THE PANCREAS AND ADJOINING VISCERA FROM BEFORE. One-third natural size

The liver, the stomach, the greater part of the small intestine, and the transverse colon have been removed. *P*, pancreas; *d*, duodenum; *d.j.*, duodeno-jejunal flexure; above the duodenum, and between it and the head of the pancreas, are seen the bile-duct, portal vein, and hepatic artery; *asc. col.*, *desc. col.*, ascending and descending colon; *spl.*, spleen; *r.k.*, *l.k.*, right and left kidneys; *s.r.*, *s.r′.*, right and left suprarenal glands; *pt.* peritoneum at the back of the abdominal cavity; *m.* line of reflexion of the mesentery; the line of reflexion of the transverse mesocolon is seen along the lower edge of the pancreas and crossing the duodenum.

Surfaces and borders.—When hardened *in situ*, the spleen has, according to Cunningham,[1] the shape of an irregular tetrahedron, with its apex above and its base below. Its four surfaces are termed *diaphragmatic*, *renal*, *gastric*, and *basal*. Of these, the *diaphragmatic* is large and convex, and lies against the diaphragm. In the greater part of its extent it looks upwards, backwards, and to the left, but near its upper end somewhat inwards. It is separated from the ninth, tenth, and eleventh ribs not only by the peritoneum and the diaphragm, but also in about its upper third by the left lung, and in nearly its whole extent by the left pleura. The left lobe of the liver is occasionally found in the adult to extend backwards and to the

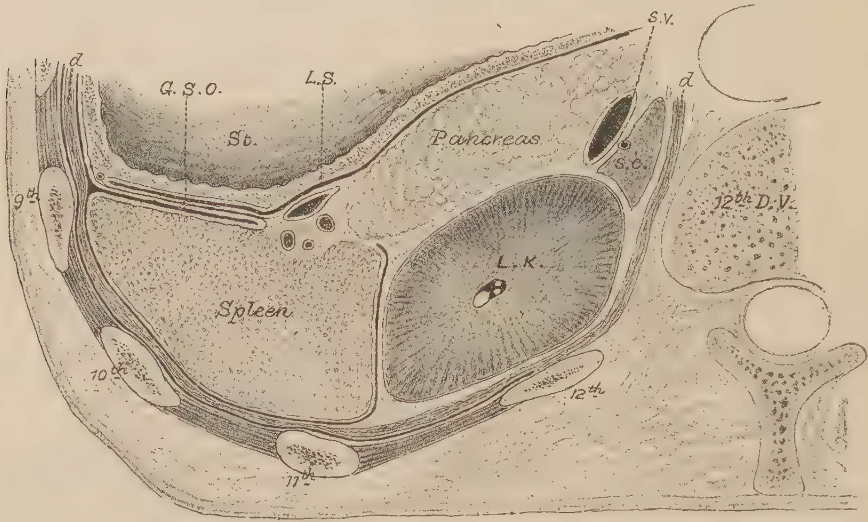


FIG. 285.—HORIZONTAL SECTION OF THE ABDOMEN OF AN ADULT MALE AT THE LEVEL OF THE LOWER BORDER OF THE BODY OF THE TWELFTH THORACIC VERTEBRA, SEEN FROM ABOVE. Slightly reduced from natural size. (J. Symington.)

left on to the upper part of the diaphragmatic surface, but in the fetus it normally occupies this position. The *renal* surface is generally flat, and narrower than the gastric, and does not reach so high as either the gastric or diaphragmatic surfaces. Above, it generally touches the suprarenal gland, and in the rest of its extent is in close relation with the outer aspect of the left kidney. It looks inwards and downwards. The *gastric* surface is concave, and looks forwards and inwards. In the greater part of its extent it lies against the posterior surface of the stomach, but towards its lower end, and behind its hilum, it touches the tail of the pancreas. This surface presents, parallel to and near its inner border (see fig. 282), a long fissure, or, more frequently, a series of depressions, termed the *hilum*, through which the vessels and nerves enter the spleen, and around which the peritoneum is reflected from the surface of the organ. The upper and inner extremity of the spleen is directed inwards, and reaches to about 3 cm. from the left side of the vertebral columnn, usually opposite the body of the eleventh thoracic vertebra. The lower and outer end is blunt, and presents a triangular area, which may be termed the *basal* surface (Cunningham). It lies against the tail of the pancreas, the splenic flexure of the colon, and the costo-colic ligaments. If the tail of the pancreas be unusually large (see fig. 81), it may separate the colon entirely from the spleen; occasionally, with the splenic flexure of the colon contracted, some convolutions of the jejunum may be applied to the basal surface.

[1] 'On the Form of the Spleen and the Kidneys,' *Jour. Anat. and Phys.*, vol. xxix., July 1895.

Of the borders of the spleen, the *anterior*, situated between the gastric and diaphragmatic surfaces, is the most prominent, and is usually marked near its lower end by one or two notches. Traced from its inner end, it is seen to curve outwards with the convexity of the curve upwards. This part of the anterior border reaches forwards and upwards between the diaphragm and the stomach nearly as high as the fundus of the stomach. Towards the left side, this border turns downwards and somewhat forwards, being in close contact with the chest wall near the mid-axillary line and nearly parallel to the ninth rib. The *posterior* border is between the renal and the diaphragmatic surfaces. It is indistinct above, but lower down becomes well marked, sometimes dipping slightly inwards between the diaphragm and the kidney. It is inclined downwards and outwards, opposite the lower border of the eleventh rib. The anterior and posterior borders are united by an *inferior* border, which separates the diaphragmatic and renal surfaces. The inner border lies slightly internal to the hilum. It joins the anterior border above, and, passing downwards slightly internal to the hilum, separates the gastric and renal surfaces.

Relation to peritoneum (see figs. 283, 284).—The spleen is almost entirely covered by peritoneum, which is firmly connected with its capsule. It also gives attachment to two peritoneal folds—the gastro-splenic ligament and the lieno-renal ligament. The gastro-splenic ligament consists of two layers of peritoneum, which pass from the front of the hilum of the spleen, forwards and outwards, to the posterior surface of the stomach near its left border. If the outer of these layers be traced over the spleen, it will be found to cover the gastric surface to the left of the hilum, the diaphragmatic surface, and the posterior part of the renal surface. It is then reflected on to the kidney, forming the posterior layer of the lieno-renal ligament. The inner layer of the gastro-splenic ligament is derived from the lesser sac, and is continued into the anterior layer of the lieno-renal ligament. Below, the two layers of the gastro-splenic ligament are continuous with the great omentum. The splenic vessels pass to the spleen between the layers of the lieno-renal ligament. The lower part of the renal surface of the spleen is often uncovered by peritoneum, the posterior layer of the lieno-renal ligament being reflected from near the posterior border of the spleen on to the kidney (see fig. 80).

Variations.—Parsons[1] found notches on the posterior and inferior borders and fissures on the diaphragmatic surface of the spleen, in addition to the notches usually described on the anterior border. The anterior border was destitute of notches in eight out of 113 specimens examined; two was the commonest number, but in one case there were seven. Notches on the posterior border occurred in 32 per cent., and on the inferior border in 8 per cent. of the cases. The fissures on the diaphragmatic surface do not appear to represent the persistence of a primitive lobulation, but are apparently 'secondary developments caused by a crumpling of the viscus through pressure, and by its growth being checked by traction at certain points.'

Accessory spleens.—Small detached roundish nodules are occasionally found in the neighbourhood of the spleen similar to it in substance. These are commonly named accessory or supplementary spleens (*splenculi, lienculi*). One or two most commonly occur, but a greater number—and even up to twenty-three—have been met with. They are small rounded masses varying from the size of a pea to that of a walnut. They may be found along the borders of the spleen—especially the anterior—and in the hilum. They also occur some little distance from the spleen—as in the great omentum, transverse mesocolon, and gastro-lienal ligament, and, near the pancreas, embedded in the connective tissue surrounding the splenic vessels (see Haberer, 'Lien succenturiatus und Lien accessorius,' *Arch. f. Anat.*, 1901).

Spleen in the infant.—The spleen is relatively slightly larger in the new-born child than in the adult, but the peculiarities in the infant are mainly due to the large size of the liver and suprarenal gland. The under-surface of the left lobe of the liver is normally in contact with it at birth, and, according to Ballantyne, the hepatic area of the spleen is larger than any of the other surfaces. The same observer suggests that the renal surface in the new-born infant is more appropriately named the suprarenal, as this organ lies in contact with it and separates it in almost the whole of its extent from the kidney.

[1] 'On the Notches and Fissures of the Spleen and their Meaning,' *Jour. Anat. and Phys.*, vol. xxxv., April 1901.

STRUCTURE OF THE SPLEEN.

The spleen has two membranous investments—a *serous coat* derived from the peritoneum, and a *fibrous coat* (*tunica propria*). The soft substance (*pulp*) of the organ is supported by a reticular framework of fibrous and muscular bands (*trabeculæ*).

The **serous coat** is thin, smooth, and firmly adherent to the tunica propria beneath. It closely invests nearly the whole surface of the organ.

The **tunica propria** (fig. 286), much thicker and stronger than the serous coat, is whitish in colour and highly elastic. It is continuous with the trabecular structure within. Along the hilum, this coat is reflected into the interior of the

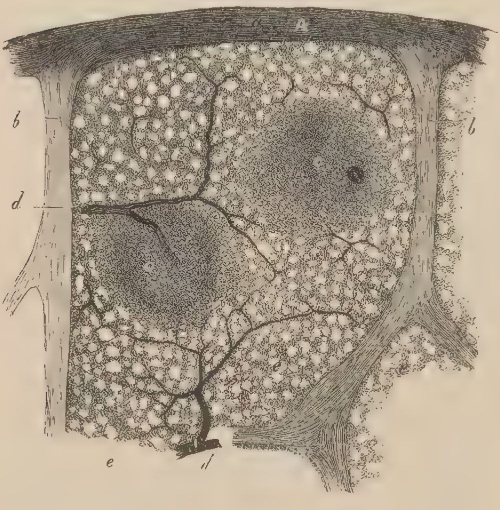


Fig. 286.—Vertical section of a small superficial portion of the human spleen. Magnified with a low power. (From Kölliker.)

A, tunica propria; *b*, trabeculæ; *c c*, Malpighian corpuscles, in one of which an artery is seen cut transversely, in the other longitudinally; *d*, injected arterial twigs; *e*, spleen-pulp.

Fig. 287.—Small artery from the dog's spleen with Malpighian corpuscles attached. Magnified ten diameters. (Kölliker.)

spleen, in the form of large trabeculæ, supported and enclosed by which run the blood-vessels and nerves; so that these are ensheathed by prolongations of the fibrous coat. These sheaths ramify with the vessels which they include, as far as their finer subdivisions, and are connected with numerous trabecular processes which pass into the interior from the whole inner surface of the fibrous coat. The arrangement of the sheaths and trabeculæ may be easily displayed in the spleen of the ox by pressing and washing out the pulp from a thick section; and then they are seen to form a close reticulation through the substance. Thus, the fibrous coat, the sheaths of the vessels, and the trabeculæ, all of a highly elastic nature, constitute a distensible framework, which contains in its interstices or areolæ the red pulp. These fibrous structures are composed of interlaced bundles of areolar tissue containing a large amount of fine elastic tissue, and a few plain muscular fibre-cells. In the spleen of the pig, the dog, and the cat, and to a smaller extent in that of the ox and sheep, there is a far more abundant admixture of muscular tissue, and this tissue exhibits a regular rhythmic contractility (Roy).

The **pulp** of the spleen is of a dark reddish-brown colour: when pressed out

from between the trabeculæ it resembles venous blood, and, like that, acquires a brighter hue on exposure to the air. In fact, what is thus pressed out from the dead spleen is mainly clotted blood. The pulp consists of a reticulum of fine fibres continuous with the trabeculæ and covered by branched connective-tissue corpuscles. The interspaces between these cells are occupied by blood, but with a rather larger proportion of white corpuscles than in ordinary blood.

Blood-vessels, lymphatics, and nerves.—The **splenic artery** (*arteria lienalis*), which supplies the spleen, is the largest branch of the cœliac axis. It takes a tortuous course to the left, along the upper border of the pancreas, and divides into a number of branches, these do not anastomose with one another, but entering the hilum, are distributed as terminal arteries to different areas of the organ. The vessels first ramify along the trabecular sheaths, and, as they become smaller, are

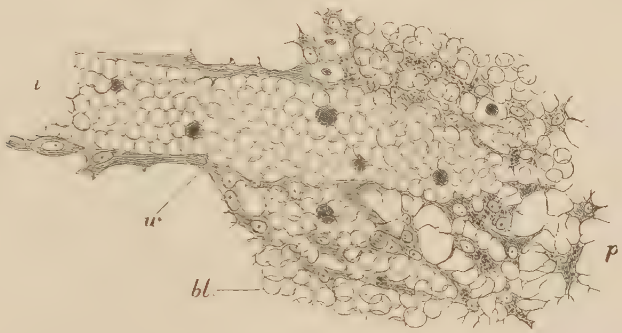


FIG. 288.—THIN SECTION OF SPLEEN-PULP, SHOWING THE MODE OF ORIGIN OF A SMALL VEIN. Highly magnified. (E. A. Schaefer.)

v, the vein, filled with blood-corpuscles, which are in continuity with others, *bl*, filling up the interstices of the retiform tissue of the pulp. At *p* the blood-corpuscles have been omitted from the figure, and the branched cells are better seen; *w*, wall of the vein. The shaded bodies amongst the red blood-corpuscles are pale corpuscles.

invested by an adventitia derived from the trabeculæ. This adventitia becomes transformed into lymphoid tissue, which forms a comparatively thick sheath along each. The vessels then divide into small tufts of arterioles arranged in pencils (fig. 287). The lymphoid sheath is abruptly dilated here and there into small oval or spheroidal enlargements, measuring on an average 0·36 mm. in diameter, but varying in size from much smaller than this up to 1 mm., and closely resembling the lymphoid follicles met with in the intestine and elsewhere. These lymphoid expansions may be seen on the surface of a fresh section of the organ as light-coloured spots scattered in the dark substance composing the pulp, and have been long noticed and described as the **Malpighian corpuscles** (*noduli lymphatici lienalis*) of the spleen (fig. 287). In some cases, the corpuscle is developed upon one side only of the arterial wall, upon which it then appears to be sessile; whilst in other instances —and this is the most frequent in the human subject—the expansion takes place all round the circumference of the vessel, by which it then appears to be pierced. In either case the artery sends off radiating branches to be distributed in the Malpighian corpuscle.

The arteries terminate in capillary vessels, which soon lose their tubular character; the cells which compose their wall becoming partially separated from one another by elongated clefts; those at the extremity of the capillary have branching processes, and are united by these with the branched connective-tissue cells of the pulp. In this manner the blood can flow directly into the interstices of the pulp

tissue. The **veins,** which form a network of intercommunicating spaces within the pulp, commence in the same manner as the capillaries terminate: that is to say, the layer of flattened cells which lines and mainly composes their walls, on being traced back, loses its epithelioid character, and the cells, becoming thickened and spindle-shaped, and their nuclei prominent, are found to be separated here and there from each other, and to be connected by processes with the cells of the pulp (fig. 288). The small veins take a different course from the arteries; for they soon pass to the trabeculæ, and are conducted upon and within these, freely joining and anastomosing; whereas the arteries appear to have few or no anastomoses within the substance of the organ.

The splenic vein ends by joining the superior mesenteric to form the vena porta, which breaks up into branches within the liver.

The **lymphatics** of the spleen form two systems: a *trabecular* and a *perivascular*. The vessels belonging to the former system run in the trabeculæ, and are in communication with a superficial network in the capsule. The perivascular lymphatics take origin in the interstices of the lymphoid tissue which ensheaths the smaller arteries, and which forms the Malpighian corpuscles; they do not, therefore, at first, form distinct vessels. Lymphatic vessels have not been traced into the splenic pulp. The vessels, few in number, leave the spleen at the hilum and pass to some glands situated just outside the organ.

The **nerves**, derived from the cœliac plexus, surround and accompany the splenic artery and its branches. They are most probably distributed to the vessels and plain muscular tissue of the framework.

GLANDULA THYROIDEA.

The **thyroid** gland is a soft, brownish-red, and highly vascular organ, consisting of two lateral lobes (**lobus dexter et sinister**), generally united towards their lower ends by a transverse portion named the **isthmus.** Viewed as a whole, it is convex on its external and anterior aspects, forming a rounded projection upon the trachea and larynx, which is often distinctly visible in the living body, especially in thin individuals.

Relations.—It is covered by the skin, the superficial and deep layers of the cervical fascia, and the sterno-hyoid, omo-hyoid, and sterno-thyroid muscles—the last-mentioned being in close contact with the lateral lobes. The sterno-cleido-mastoid muscles also overlap it. Its deep surface is concave where it rests against the trachea and larynx, and, external to these structures and the inferior laryngeal nerves, its lateral lobes extend backwards to the sides of the pharynx and œsophagus. In consequence of the deviation of the œsophagus to the left side, the lower end of the left lateral lobe lies slightly in front of that structure. The lateral lobes also pass outwards in front of the common carotid arteries, the carotid sheaths intervening. Each lateral lobe is somewhat conical in form with the apex upwards, and extends from the fifth or sixth ring of the trachea to the side of the thyroid cartilage, of which it covers the inferior cornu and adjacent portion of the lamina. The transverse portion or isthmus commonly lies across the second, third, and fourth rings of the trachea, but is very inconstant in size, shape, and position. From the upper part of the isthmus, or from the adjacent portions of one of the lobes, a slender conical process, called the **lobus pyramidalis,** often proceeds upwards to the hyoid bone, to which it is attached by fibrous or muscular tissue (fig. 290). The thyroid gland is connected to the trachea and larynx by fibrous tissue, so that it follows the movements of these organs. In front, the pre-tracheal fascia extends from the isthmus and adjacent portions of

the lateral lobes upwards to the front of the cricoid cartilage and the lower border of the thyroid cartilage, forming a somewhat indistinct *anterior ligament* of the gland. Further, each lateral lobe is attached by a firm band of fibrous tissue—the

A

B

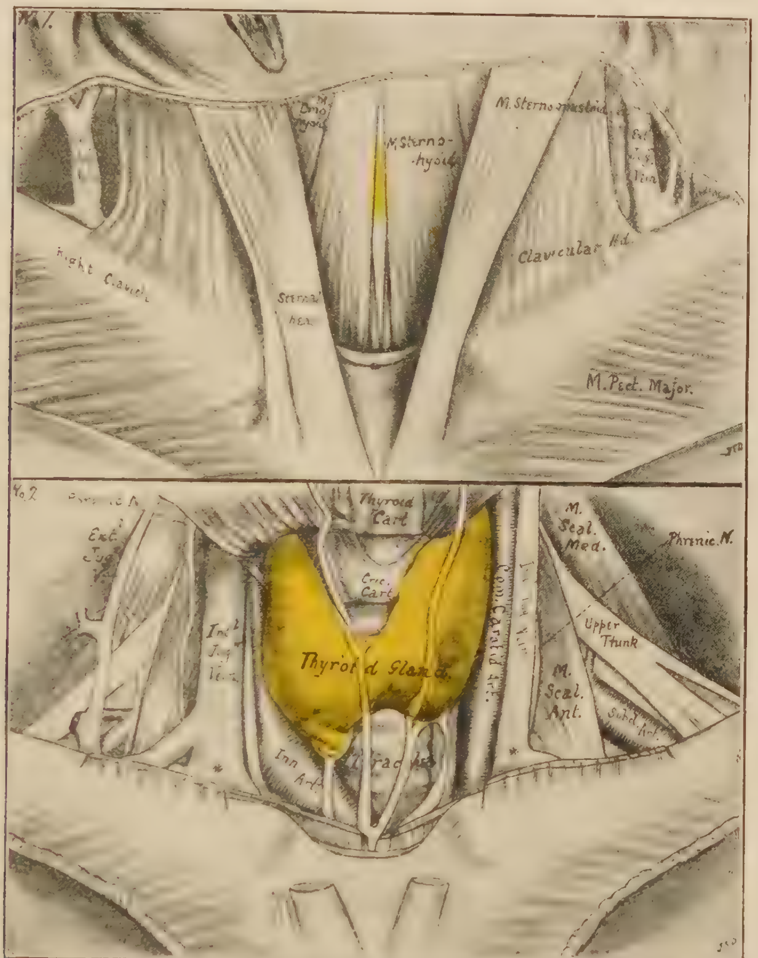


FIG. 289.—TWO DISSECTIONS OF THE FRONT OF THE NECK OF A MAN AGED FIFTY-SEVEN YEARS, EXPOSING THE THYROID GLAND. About half natural size. (J. S. Dickey.)

A, skin and fascia removed, and the sterno-cleido-mastoid, sterno-hyoid, omo-hyoid, and median edges of sterno-thyroid muscles defined. The isthmus of the gland is seen between the two sterno-hyoid muscles. B, deeper dissection. The muscles superficial to the gland have been reflected.

lateral ligament—to the side of the cricoid cartilage and the first two or three rings of the trachea.[1]

Size, weight, and colour. The size of the thyroid gland is considerably affected by the degree to which its blood-vessels may happen to be distended; while the glandular elements present are subject to marked individual variations in size, so that any estimate of the dimensions of the gland can only be approximate. The greatest transverse diameter is about 5 cm., the vertical

[1] J. Berry, 'Suspensory Ligaments of the Thyroid Gland,' *Proc. Anat. Society, Jour. Anat. and Phys.*, vol. xxii., July 1888; and Sebileau, 'Le capsule et les ligaments du corps thyroïde,' *Bull. Soc. Anat.*, Paris, 1888.

extent of each lateral lobe about the same, and of the isthmus 1 cm. to 2 cm., and the antero-posterior diameter of the lateral lobes 2 cm., and of the isthmus about 0·5 cm.

The weight of the thyroid body is ordinarily 30 grms. to 40 grms. It is generally larger in females than in males, and appears in many of the former to undergo a periodic increase about the time of menstruation. In the fetus, and during early infancy, this organ is relatively larger than in after-life; its proportion to the weight of the body in the new-born infant being that of 1 to 240 or 400, whilst at the end of three weeks it becomes only 1 to 1160, and in the adult 1 to 1800 (Krause).

Its colour is usually of a dusky brownish red, but sometimes of a yellowish hue.

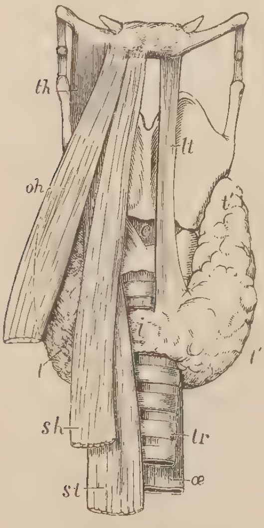


Fig. 290.—Sketch showing the form and position of the thyroid body. One-half natural size. (Allen Thomson.)

The larynx and surrounding parts are viewed from before; on the right side, the muscles covering the thyroid body are retained, on the left side they are removed; *h*, hyoid bone; *th*, right thyro-hyoid muscle; *oh*, omo-hyoid; *sh*, sterno-hyoid; *st*, sterno-thyroid; *c*, crico-thyroid membrane; *tr*, trachea; *œ*, œsophagus; *t*, right lobe of the thyroid body; *t'*, the left lobe; *i*, the isthmus; *lt*, the fibrous or muscular band termed levator thyroideæ, which is more rarely found in the middle line or to the right side, and which existed in the case from which the figure was taken.

Morphology.—Developmentally, the thyroid gland is a part of the alimentary canal, being formed by an outgrowth from the primitive pharynx, and, therefore, lined by endoderm. In the larval form of the Cyclostomes (Ammocœtes), a homologous structure, known as the endostyle, is formed, which is of a glandular nature, and discharges its secretion into the alimentary canal. In the adult Cyclostomes (Petromyzon), and in all the Vertebrates—from fishes to mammals—the pharyngeal outgrowth becomes shut off from its primitive connexion with the pharynx, and develops into a number of closed vessels lined by cells of endodermic origin. The secretion of these cells is discharged into the cavity of the vesicle, and certain constituents are apparently absorbed into the blood as an internal secretion.

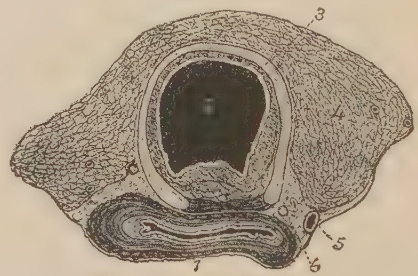


Fig. 291.—Horizontal section of trachea, œsophagus, and thyroid body. Natural size. (J. Symington.)

1, œsophagus; 2, cavity of trachea; 3, cartilaginous ring of trachea; 4, thyroid body; 5, inferior thyroid artery; 6, inferior laryngeal nerve.

It is generally admitted that the greater part of the thyroid is developed from a median outgrowth on the ventral wall of the pharynx, behind the tuber impar of the tongue; and some authorities have also described two lateral outgrowths from the fourth branchial pouches, but it is now generally held that no part of the thyroid gland proper is derived from this source.

Variations.—Most of the variations in the thyroid gland are due to a partial persistence of the median or glosso-thyroid duct. The most obvious example of this persistence is the **lobus pyramidalis,** which Streckeisen [1] met with in 104 out of 153 cases, or nearly 68 per cent.; while Marshall [2] found it in only 24 out of 60 cases, or 40 per cent. It is usually

[1] Streckeisen, 'Beiträge zur Morphologie der Schilddrüse,' *Virch. Arch. f. path. Anat.*, 1886.

[2] Marshall, C. F., 'Thyro-glossal Duct, or Canal of His.' *The Journ. of Anat. and Physiol.*, vol. xxvi., 1891; 'Variations in the Form of the Thyroid Gland in Man.' *Journ. Anat. and Phys.*, vol. xxix., Jan. 1895.

attached below to the isthmus on the left side of the median plane, but it may join one or other of the lateral lobes, and above it is connected with the hyoid bone. Out of the 104 specimens in which the pyramidal process was found by Streckeisen to be present, 55 were glandular up to the hyoid bone; in 12 the process was connected to that bone by fibrous tissue, and in 2 by muscle. The muscular fasciculi, which are occasionally found to descend from the hyoid bone to the thyroid gland, or its pyramidal process, are known as the *levator glandulæ thyroideæ* (fig. 290). The fibres are most frequently derived from the thyrohyoid muscle, but occasionally they are independent. In one of Marshall's cases there were two pyramidal processes; while in another a single process divided into two parts, one for each lateral lobe. Accessory thyroids may be formed by transverse division of the pyramidal process into several separate masses; more rarely they are found in relation

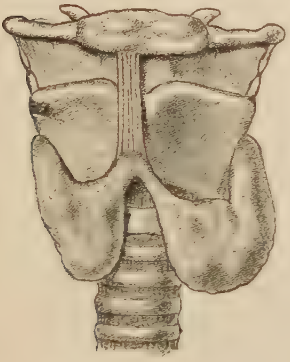


FIG. 292.—A THYROID GLAND SHOWING BIFURCATION OF THE LOWER END OF PYRAMIDAL PROCESS, ONE PART GOING TO EACH LATERAL LOBE. (C. F. Marshall.)

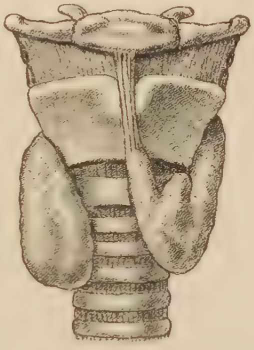


FIG. 293.—A THYROID GLAND WITH PYRAMIDAL PROCESS ATTACHED TO LEFT LOBE OF GLAND, ISTHMUS ABSENT. (C. F. Marshall.)

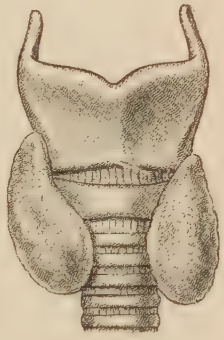


FIG. 294.—A THYROID GLAND WITH BOTH PYRAMIDAL PROCESS AND ISTHMUS ABSENT. (C. F. Marshall.)

with the lateral lobes. The small glandular masses resembling in structure the thyroid, which are frequently found in front of or above the hyoid bone, are derived from the upper part of the thyro-glossal duct.

As a rule, the two lateral lobes are approximately equally well developed, but occasionally they are very unequal in size, and in rare cases one lateral lobe may be entirely absent. The isthmus varies greatly in size, and not infrequently it is absent.

Structure.—The thyroid is invested by a thin transparent layer of dense areolar tissue, which connects it with the adjacent parts, and imperfectly separates its substance into small lobules of irregular form and size. In the interstitial connective tissue of the gland there occur a number of cells similar to the 'plasma-cells' of Waldeyer ('parenchyma-cells,' Baber).

When the organ is cut into, a yellow glairy fluid (*colloid*) escapes from the cut surface. Embedded in its substance are multitudes of closed *vesicles* (fig. 295), which are held together in groups or imperfect lobules by areolar tissue. The size of the vesicles varies from 0·045 mm. to 1 mm., being then visible to the naked eye. They are spherical, polyhedral, or flattened in shape. The wall of each vesicle consists of a simple layer of cubical or columnar epithelium-cells, which, according to Langendorff, are of two kinds: namely—those which are actually secreting the material of the contents of the vesicles (*colloid cells*) and others (*reserve cells*) which may take the place of the colloid cells that have become detached or mingled with the secretion. The amount of colloid material contained within the vesicles varies considerably. An excessive accumulation of colloid substance frequently occurs, and in goïtre the vesicles may become enormously distended. The secretion of the thyroid is essential to health, and a condition known as myxœdema or cretinism may result from its removal or congenital absence.

Vessels, lymphatics, and nerves.—The **arteries** of the thyroid gland are the *superior and inferior thyroids* of each side, to which is sometimes added a fifth vesssel, the *thyroidea ima.* The branches of the thyroid arteries run along the borders and over the surfaces of the gland, where they anastomose freely with one another. The arteries divide into comparatively small vessels before they penetrate into the gland substance, where they have a lobular distribution. There is a rich capillary network around each vesicle. The **veins**, which are also large, ultimately form plexuses on the surface, from which the *superior, middle,* and *inferior thyroid veins* are formed on each side. The superior and middle thyroid veins open into the internal jugular; the inferior veins issue from a plexus formed in

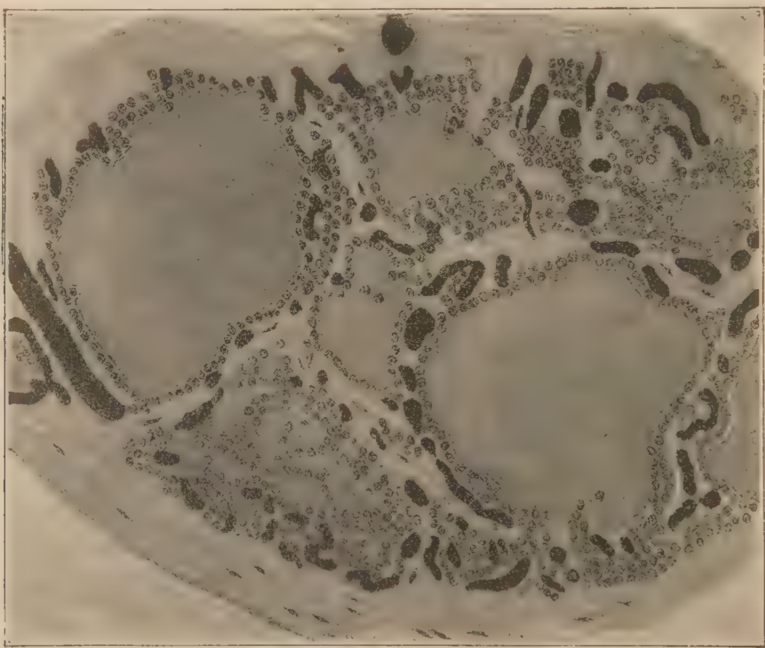


Fig. 295.—Section of human thyroid. Highly magnified. (Major.)
The close relationship of the capillaries to the epithelium of the vesicle is well shown.

front of the trachea, and open into the innominate veins. The thyroid gland is one of the most vascular organs in the body—indeed, it has been estimated by Tschuewsky[1] that it is about five and a half times as vascular as the kidney, and that in the dog the entire amount of blood in the body flows through the gland sixteen times in a day.

Lymphatics.—As the thyroid is a gland without ducts it has been supposed that the lymphatic vessels might serve as channels for the discharge of the colloid material in the vesicles, and this substance has undoubtedly been found in the neighbouring lymphatic vessels; but an actual communication between the cavity of the vesicles and the lymphatics has not been satisfactorily demonstrated. The lymphatic vessels form a rich plexus both in the substance of the gland and on its superficial and deep surfaces, but there is only a slight connexion in man between the vessels of the right and left lobes. The vessels leaving the gland follow in the main arteries and end in the pre-laryngeal, pre-tracheal, para-tracheal, median deep cervical, and supreme anterior mediastinal glands (Bartels).

[1] 'Der Blutstrom in der Schilddrüse,' *Pfluger's Arch.*, Bd. xcvii., 1903.

The **nerves** are derived from the *middle* and *inferior cervical ganglia* of the sympathetic. They accompany the blood-vessels. According to Anderson, there are no ganglion-cells in their course. Their branches extend close to the base of the epithelium cells.

GLANDULÆ PARATHYROIDEÆ.

The small parathyroid glands (fig. 296) are four in number, arranged in pairs, and usually situated in close proximity to the lateral lobes of the thyroid gland. One pair is placed above and behind the other, so that they may be termed postero-superior and antero-inferior respectively.[1] The postero-superior parathyroid of each side is more constant and more readily found than the antero-inferior. It lies near the level of the lower border of the cricoid cartilage, between the muscular wall of the pharynx or œsophagus internally, and the posterior margin of the lateral lobe of the thyroid gland externally. The pre-vertebral fascia is behind it, and also sometimes the lateral ligament of the thyroid gland. The antero-inferior parathyroid is more variable in its position and more indefinite in its relations. It often lies at the side of the trachea, opposite about the third or fourth rings and near the lower border of the lateral lobe of the thyroid gland, or some little distance below it. According to Welsh, the postero-superior parathyroid is behind the branches of the inferior thyroid artery and the antero-inferior in front; but E. Fischer[2] maintains that both bodies are normally anterior to the artery.

Fig. 296.—Transverse section of the left lobe of the thyroid of a two-months' kitten. Magnified twenty diameters. (Kohn.)

a, thyroid tissue; *b*, *b*, thymus tissue; *p*.*p*′, parathyroid glands.

The parathyroids cannot easily be distinguished by the naked eye from small accessory thyroid glands, detached portions of thymus tissue, small lymphatic nodules, or even lobules of fat. They are invested by a fibrous capsule, even when more or less completely embedded in the thyroid gland.

Form, colour, size, and weight. They are smooth, flat disks, with a more or less distinctly marked oval outline, and sometimes the narrow end tapers into a fine stalk. In young subjects they are of a pale rose colour and almost transparent, but with age they tend to become yellow or yellowish brown. Their size varies considerably, but on an average they are about 6 mm. long, 3 mm. to 4 mm. broad, and 1·5 mm. to 2 mm. in thickness. They rarely exceed 12 mm. in length. In weight, they vary from 0·01 grm. to 0·1 grm.

Structure.—The parathyroids are composed of epithelium-like cells arranged in anastomosing columns, with very vascular connective tissue between

[1] D. A. Welsh, 'Concerning the Parathyroid Glands,' *Jour. Anat. and Phys.*, vol. xxxii.
[2] 'Die Glandulæ parathyreoideæ des Menschen,' *Arch. f. Anatomie*, 1911.

the columns. In some cases the cells may surround a central space which contains colloid material. The arterial supply is derived from the inferior thyroid artery, and between the arteries and the veins there are sinusoids.

These bodies were first carefully described and named glandulæ parathyroideæ by Sandström,[1] in 1880; and in the following year, Baber [2] recognised them as 'undeveloped areas' of the thyroid gland; but they had undoubtedly been previously observed by Remak, Virchow, Paget, and others. During the last two decades, numerous papers have appeared dealing with their embryology, histological structure, and functions. Like the thyroid gland, they belong developmentally to the alimentary canal, being formed by outgrowths from the third and fourth pharyngeal pouches, and are therefore included in the group of organs termed branchiogenic. Many investigators consider them to be entirely distinct in structure and function from the thyroid; but there is some evidence in favour of the view that they may exhibit a tendency to form vesicles containing a colloid material. They are believed to be essential to life, and their removal has been followed by severe nervous symptoms known as 'tetany.' In most mammals [3] there are two pairs of parathyroids; but in some only one pair, and in others three or four pairs.

THYMUS.

The thymus forms a glandular mass, the greater part of which is situated in the anterior and superior mediastinal spaces of the thorax, while the smaller portion extends into the neck. Developmentally, it is a paired organ, consisting of a *lobus dexter* and *lobus sinister*, and the upper part usually appears in the neck in the form of two distinct and separate processes, one on each side; but these unite at the upper part of the thoracic cavity to form an apparently single organ, which is seldom bilaterally symmetrical, or divided by a distinct fissure into two parts, as represented by Sappey (fig. 298). On dissection, it can generally be separated into two portions, which overlap one another in an irregular manner, while the connective-tissue septum between them is very thin.

Relations.—These vary according to the age of the subject and the size of the organ. In a newly born infant, who has not breathed, the thymus forms a large and conspicuous structure in the upper and anterior part of the thoracic cavity, extending downwards behind the manubrium sterni and the upper part of the body of the sternum and the first three or four costal cartilages, and reaching on each side to the edge of the uninflated lung (fig. 297). It covers the great vessels above the heart, and extends downwards over a large portion of the pericardium. On each side it passes backwards, median to the lung, on which it forms a large and well-marked impression, as far as the root of the lung. At this period of life, the pleuræ extend inwards considerably beyond the lungs and cover the greater portion of the thymus. The cervical portion extends upwards in front of the trachea and behind the sterno-hyoid and sterno-thyroid muscles nearly to the thyroid gland. After birth, with the establishment of respiration and the advance of the anterior edge of the lungs forwards and inwards, the greater part of the thymus becomes covered by these organs. The downward, and especially the lateral, extensions are the first portions to atrophy, so that when persistent in the adult it has a narrower and more elongated form than in the fetus. Of the great vessels which it covers, it lies in most intimate relation with the left innominate vein, which sometimes appears to be embedded in it.

Growth, involution, and weight.—The thymus is a temporary gland,

[1] 'Om en ny Körtel hos menniskan och atokilliga doggdjur,' *Läkareförenings Förhandlingar*, Upsala, 1880.
[2] 'Researches on the Minute Structure of the Thyroid Gland,' *Phil. Trans.*, vol. clxxii., 1881.
[3] 'The Comparative Anatomy, Gross and Minute, of the Thyroid and Parathyroid Glands in Mammals and Birds,' *Jour. Anat. and Phys.*, vol. xlii., 1908.

but it has been shown by the researches of Hammar[1] that it persists, under healthy conditions, much longer than was formerly supposed, and that its involution is greatly influenced by the general state of nutrition. It appears to undergo atrophy in all diseases affecting the general nutrition, so that reliable data as to its normal size can only be obtained by the examination of cases in which death has occurred suddenly in healthy subjects. In the newly born infant, its average weight is about 12 grms.; after birth it continues to grow until puberty, when it weighs

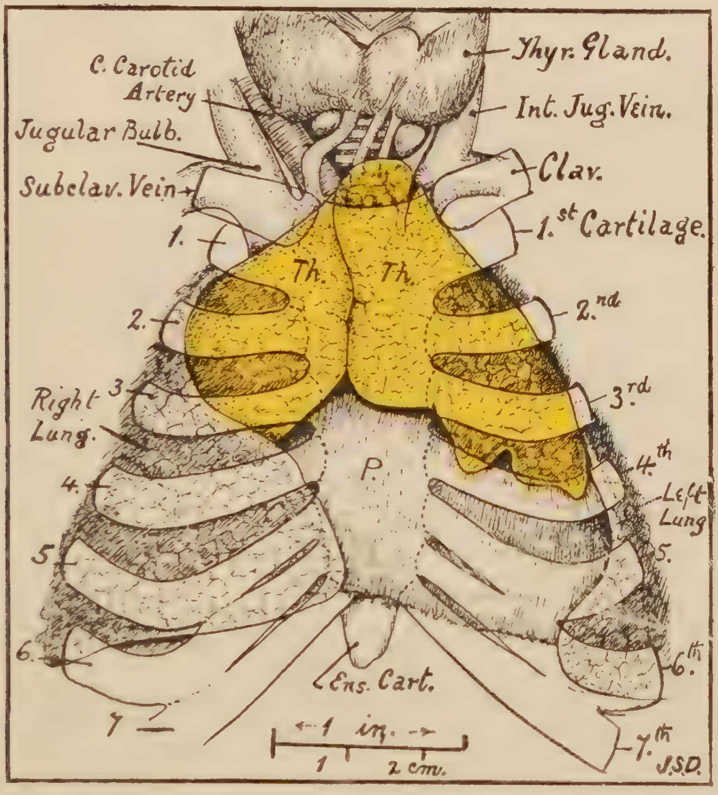


FIG. 297.—THE THYMUS GLAND OF A FULL-TIME FETUS. Natural size. (J. S. Dickey.)

The parts of the chest wall in front of the gland are shown. *Th. Th.*, thymus gland; *P*, pericardium.

about 35 grms.; subsequently, it tends to undergo a gradual process of involution, so that by the age of twenty-five years its weight is reduced to 25 grms., at sixty to less than 15 grms., and at seventy to about 6 grms. It measures at birth about 5 cm. to 6 cm. at its broadest part, and its vertical extent is from 4 cm. to 5 cm.

Structure.—The lateral lobes of the thymus gland are each invested by a thin capsule of areolar tissue, which sends partitions into the gland between the lobules; on its outer surface, the capsule is covered by a layer of flattened cells. Each lobe consists of numerous polyhedral *lobules*, connected by a more delicate intervening areolar tissue. These primary lobules are made up of a number of secondary lobules (fig. 299), one to two millimetres in diameter. Each follicle is composed of a central part or *medulla*, and an external larger part or *cortex*.

[1] 'Ueber Gewicht, Involution und Persistenz der Thymus im Postfötalleben des Menschen,' *Arch. f. Anat.*, 1906.

The cortex is subdivided by inward prolongations of the connective tissue into nodules, and each nodule consists of a fine reticulum, in the meshes of which are lymphoid cells. In the medulla, the reticulum is coarser, the lymph-cells are much less abundant, and there are scattered nests of cells which have a concentric structure, and are known as the concentric corpuscles of Hassall. The reticulum and Hassall's corpuscles are of endodermic origin, being derived from a downgrowth of the third pharyngeal cleft, while the lymphoid cells are probably mesodermic in origin.

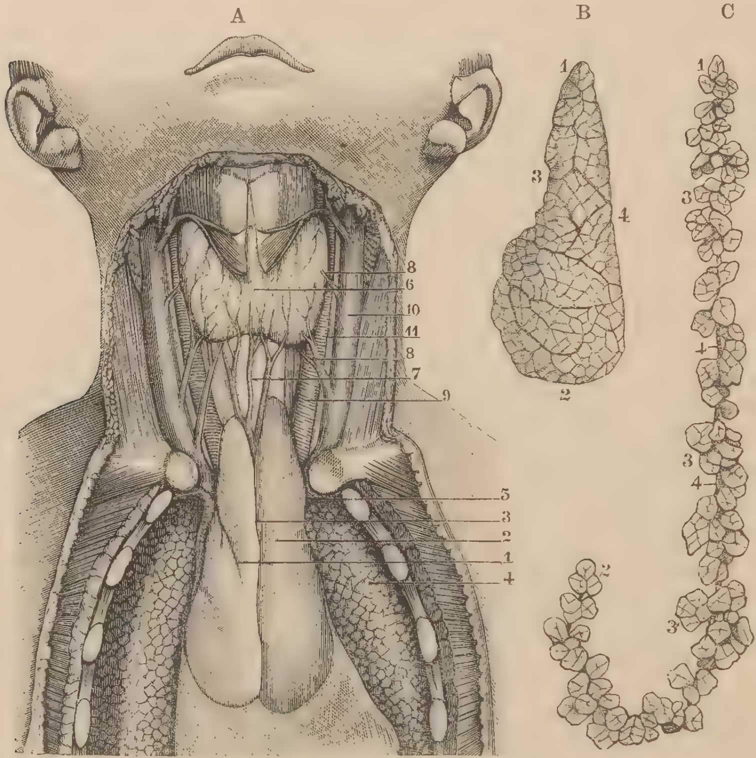


Fig. 298.—The thymus in a child of six months. (Sappey.)

A, situation, form, and relations of the gland. 1, right lobe; 2, left lobe; 3, median furrow; 4, lung, somewhat everted; 5, internal mammary vein; 6, thyroid body; 7, inferior, 8, middle thyroid veins; 9, common carotid artery; 10, internal jugular vein; 11, vagus nerve. B, right lobe of the thymus after removal of its envelope; 1, its apex; 2, its base; 3, thin outer border; 4, thick inner border. C, the gland unravelled, 1 to 2, showing the lobules, 3, grouped around a central cord; 4, the central cord or strand of connective tissue, connecting the lobules.

Blood-vessels, lymphatics, and nerves.—The **arteries** of the thymus are derived from various sources: namely—from the *internal mammary*, the *inferior* and *superior thyroid*, the *subclavian*, and *carotid arteries*. Their branches penetrate to the follicles, where they form a plexus which surrounds the cortex and from which capillaries converge towards the medulla. In some animals these vessels loop back towards the cortex, but in others they open into an inner vascular circle which lies just within the boundary of the medulla. The **veins,** for the most part, open into the *left innominate vein.*

The **lymphatics** are abundant, they accompany the blood-vessels in the gland and terminate in several small lymphatic glands lying close to the right and left lobes of the thymus.

The **nerves** are very minute. Haller thought that they were partly derived from the phrenic nerves; but, according to Cooper, no filaments from these nerves

FIG. 299.—FROM A SECTION OF THE THYMUS OF A CHILD. (E. A. Schaefer.)

c, cortex of a lobule partly separated into nodules by the trabeculæ, *tr.*; *b*, *b*, blood-vessels, and *c*, *c*, connective corpuscles in the medulla.

go into the gland, although they reach the investing capsule, as does also a branch from the descendens hypoglossi. Small filaments, derived from the vagus and *sympathetic nerves*, descend, on the thyroid body, to the upper part of the thymus. Sympathetic nerves also reach the gland along its various arteries.

GLANDULÆ SUPRARENALES.

The **suprarenal glands**, also frequently termed adrenals, are two flattened bodies, each of which surmounts the corresponding kidney (fig. 300). They are both situated in the epigastric region, one on each side of the vertebral column. They differ from one another in shape and also in their relations. The **right gland** has a flattened triangular form: one surface called *anterior* looks forwards and outwards, and the other, the *posterior*, backwards, and inwards; while the angles are directed upwards, downwards, and outwards. The *anterior surface* has a furrow, called the *hilum*, which passes horizontally a little below the upper border and vertically near the inner border. At the union of these two parts of the fissure, the suprarenal vein emerges from the organ. The area above and internal to the fissure is depressed, and forms about one-third of the anterior surface. The inner part of this area lies behind the inferior vena cava, and the upper part is in direct contact with the liver. The outer and larger portion of the anterior surface is covered by the peritoneum, which separates it from the liver, except a small area near the inferior angle, which sometimes lies against the duodenum. The *posterior surface* also has a depression dividing it into two parts: one of these, the upper and larger, lies against the diaphragm, and is

FIG. 300.—FRONT VIEW OF THE RIGHT KIDNEY AND SUPRARENAL GLAND OF A FULL-TIME FŒTUS. (Allen Thomson.)

This figure shows the lobulated form of the fœtal kidney, *r*; *v*, the renal vein and artery; *u*, the ureter; *s*, suprarenal gland: the letter is placed near the hilum, in which the large veins (*v'*) are seen emerging from the interior of the gland.

bounded below by an elevation projecting into the groove between that muscle and the kidney; the lower and smaller area is in contact with the kidney.

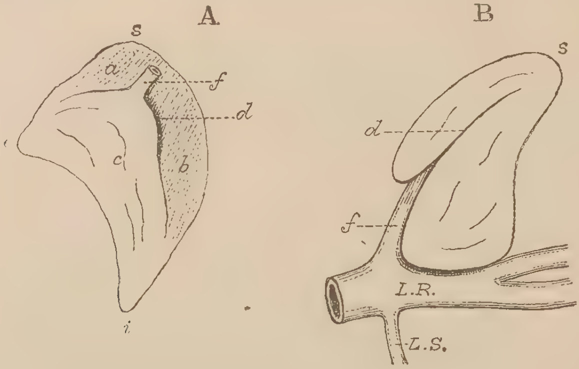


FIG. 301.—ANTERIOR SURFACE OF THE SUPRARENAL GLANDS, MODIFIED FROM ROLLESTON. (J. Symington.)

A, right gland; *s*, *e*, *i*, its superior, lateral, and inferior angles; *a*, area in direct contact with liver; *b*, area behind inferior vena cava; *c*, area below and lateral to the hilum, covered by the peritoneum and the liver, except near the inferior angle where it comes into contact with the duodenum; *d*, hilum on anterior surface; *f*, vein.

B, left gland; *s*, its superior angle; *d*, hilum on anterior surface; *f*, vein; L.R, left renal vein; L.S, left spermatic vein.

The **left suprarenal gland** is slightly larger than the right. It does not project so much above its corresponding kidney, but is prolonged downwards along the upper half of its inner border. Looked at from the front, its outline is crescentic, the concavity of the crescent being directed downwards and outwards towards the kidney. The *anterior surface* lies in contact with the upper end of the renal surface of the spleen and the stomach, near its cardiac orifice, while its lower half is crossed by the pancreas and the splenic vessels. It has a groove passing downwards and forwards, at the lower end of which the suprarenal vein emerges. The *posterior surface* is divided into two parts by a prominent vertical ridge: the area median to the ridge looking inwards and backwards and resting upon the left crus of the diaphragm, and the area lateral to the ridge, looking outwards as well as backwards, against the kidney. The median area is often in contact with the left cœliac ganglion.[1]

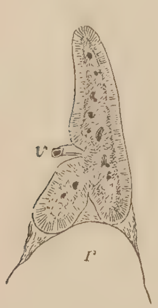


FIG. 302.—SECTION OF THE SUPRARENAL GLAND. (Allen Thomson.)

A vertical section of the suprarenal gland of a fetus, twice the natural size, showing the lower notch by which it rests on the summit of the kidney (*r*) and the hilum by which the suprarenal vein (*v*) issues, together with the distinction between the medullary and cortical substance.

The suprarenal glands measure from 30 mm. to 60 mm. from above downwards, and about 30 mm. from side to side; their thickness is from 4 mm. to 6 mm., the left being usually thicker than the right. The weight of each in the adult is about 4 grms., the left being slightly the heavier. They are nearly as large at birth as in adult life.

Structure.—Besides a covering of areolar tissue, mixed frequently with much fat, the suprarenal glands have a thin fibrous investment. On the exterior, their colour is yellowish or brownish yellow. When cut into (fig. 302), they are seen to consist of two substances: one, *external* or *cortical*, of a deep yellow colour, firm and

[1] The above description is based largely upon the account of these organs given by H. D. Rolleston (*Journal of Anatomy and Physiology*, vol. xxvi., 1892).

striated, and forming the principal mass of the organ; the other, *internal* or *medullary*, in the adult of a dark brownish-black hue, and so soft and pulpy that some of the older anatomists erroneously described a cavity within it, these glands thus acquired the name of 'capsules.'

The **fibrous coat** (figs. 303 and 304, *a*), which is distinguishable into an outer looser and an inner firmer part, is so intimately connected with the deeper parts that it cannot be removed without lacerating the subjacent structure. Its deeper layer contains plain muscular cells—at least, in some animals—and is continuous with the septa, which enter into the formation of the substance of the organ.

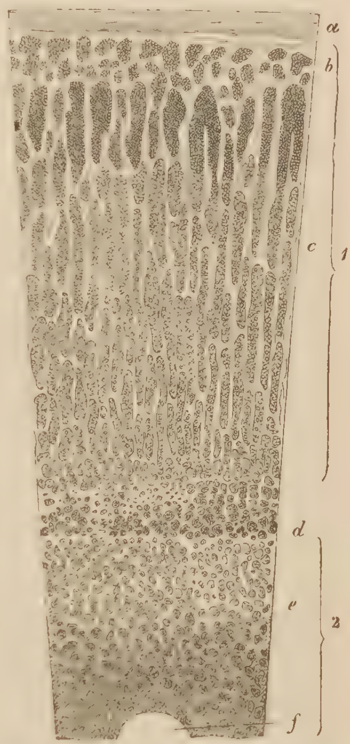


FIG. 303.—VERTICAL SECTION OF SUPRARENAL GLAND (HUMAN). Magnified. (Eberth.)

1, cortex; 2, medulla; *a*, capsule; *b*, zona glomerulosa; *c*, zona fasciculata; *d*, zona reticularis; *e*, groups of medullary cells; *f*, section of a large vein.

The **cortical part**, examined in a section with a low magnifying power, is seen to consist of a fibrous stroma, in which are embedded column-like, intercommunicating groups of cells, which are described as forming three zones (fig. 303, *b*, *c*, and *d*). The cortex is derived from the cells lining the cœlom on each side of the root of the mesentery, and it is relatively very thick during fetal life. These cells have formed within them small particles of a fatty nature (lipoids), to which the yellow colour of the cortex is due.

The **medullary part** (fig. 303, 2) is marked off from the cortical part by a layer of loose connective tissue. In the thinner parts of the adult organ there is no medullary part, and the layer of connective tissue referred to is found separating the deep surfaces of two opposed portions of the cortical part; but in the young state, the distinction of cortical and medullary portions probably extends throughout the whole gland. The medullary part is pervaded by large venous capillaries, which receive the whole of the blood which has passed through the organ. These venous capillaries are supported by the fibrous stroma, which also contains—especially in man—a number of bundles of plain muscular cells disposed parallel to the course of the larger veins, and forming a complete investment to the issuing suprarenal vein (v. Brunn). The general arrangement of the stroma is reticular; in its meshes are enclosed groups of cells. These cells stain brown with chromic acid, and are hence known as *chromaphil* cells. The medulla is formed at a later period than the cortex, and is derived from the same groups of cells as those forming the sympathetic ganglia, although whether they are to be regarded as undeveloped sympathetic cells or as cells which merely lie in close apposition with the sympathetic cells, without any genetic relation to them, is still disputed.

In some of the lower Vertebrata, the two constituents—cortex and medulla—are not united to form a pair of suprarenal glands, but develop as separate organs; thus in elasmobranch fishes, the cortex is represented by an interrenal body, and the medulla by a series of paired

bodies closely related to the sympathetic. In the Reptilia, Aves, and Mammalia, definite suprarenal glands are found.

Peculiarities according to age.—The suprarenal glands are relatively large at birth: indeed, they are about the same size as in the adult. They also extend downwards on the ventral aspect of the kidneys, so that they are largely pre-renal in position. The cortex is relatively better developed at birth, as compared with the adult, than the medulla.

Varieties.—One or both glands may be absent, although this is very rarely the case. Accessory suprarenal glands are occasionally met with, varying in size from a pin's head to that of a large pea. The smaller ones have no medullary substance, but the large ones possess a medulla (Rolleston). The accessory glands are generally found near or upon the capsule, and united to it by connective tissue. Sometimes they are partially embedded in the kidney or liver, and they may be found near organs which were originally in the neighbourhood of the suprarenal glands, and have moved away from them in the process of development. As examples of such organs, may be mentioned the genital glands; thus accessory suprarenals have been described in the broad ligament of the uterus (Warthin, *American Journal of Obstetrics*, vol. xii., 1900), and on the spermatic cord (Lockwood, *Journ. Anat. and Phys.*, vol. xxxv., April 1901). Chromatin bodies without a cortex ought not to be regarded as true accessory suprarenals since the chromatin bodies are primitively independent structures and may continue to exist as such throughout life.

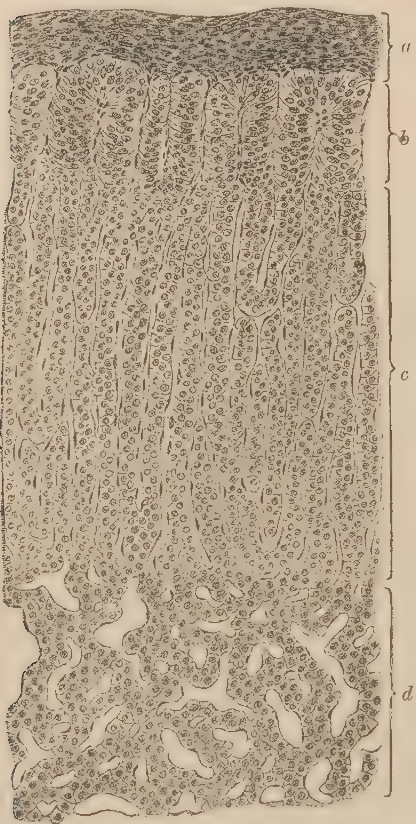


FIG. 304.—SECTION OF THE CORTEX OF A DOG'S SUPRARENAL GLAND. (Böhm and v. Davidoff.)

a, capsule; *b*, zona glomerulosa; *c*, zona fasciculata; *d*, zona recticularis.

Arteries and veins.—The suprarenal glands receive arteries from three sources: namely, from the *aorta*, the inferior *phrenic*, and the *renal* arteries. The phrenic branches are always multiple (*rami suprarenales superiores*) and may be very numerous: those from the aorta (*arteria suprarenalis media*) and renal (*arteria suprarenalis inferior*) are usually described as single, but may be represented by two or three vessels. The inferior artery is the largest; all the branches anastomose and divide freely in the surrounding fibrous and fatty capsule.[1] The veins, which pass out from the centre, are usually united into one for each organ. The right vein enters the inferior vena cava immediately, while the left, after a longer course, terminates in the left renal vein.

The small arteries, entering from the surface, run in the septa parallel to the columns, frequently anastomosing together, and surrounding each group of cells with a fine capillary network. From these capillaries the blood is continued into the medulla, where it is collected into the large venous capillaries or sinusoids and then into thin-walled veins, which unite to form one trunk, and this emerges at the hilum as the suprarenal vein.[2]

[1] For further particulars regarding the arrangement of these arteries, consult G. Gérard, 'Contributions à l'étude morphologique des artères des capsules surrénales de l'homme,' *Jour. de l'Anat. et de la Phys.*, 1913.

[2] J. S. Ferguson, 'The Veins of the Adrenal,' *Amer. Jour. Anat.*, vol. v., 1905.

Lymphatics run in the trabeculæ of the cortical substance and are connected with cleft-like spaces between the trabeculæ and the cell-columns, and even with fine clefts between the cells within the columns (Klein). They communicate with efferent-valved lymphatics both in the fibrous coat and in the medulla, where they are very numerous, forming an especially close plexus around the central vein.

Nerves.—The nerves, which are exceedingly numerous, are derived from the greater splanchnic, through the cœliac and renal plexuses. They are chiefly medullated, and lose their medullary sheath in small ganglia situated on the surface or within the organ.

THE PARAGANGLIA OR CHROMAPHIL BODIES.

Under this designation are included various small bodies which are more or less closely associated in their development with the ganglia of the sympathetic,

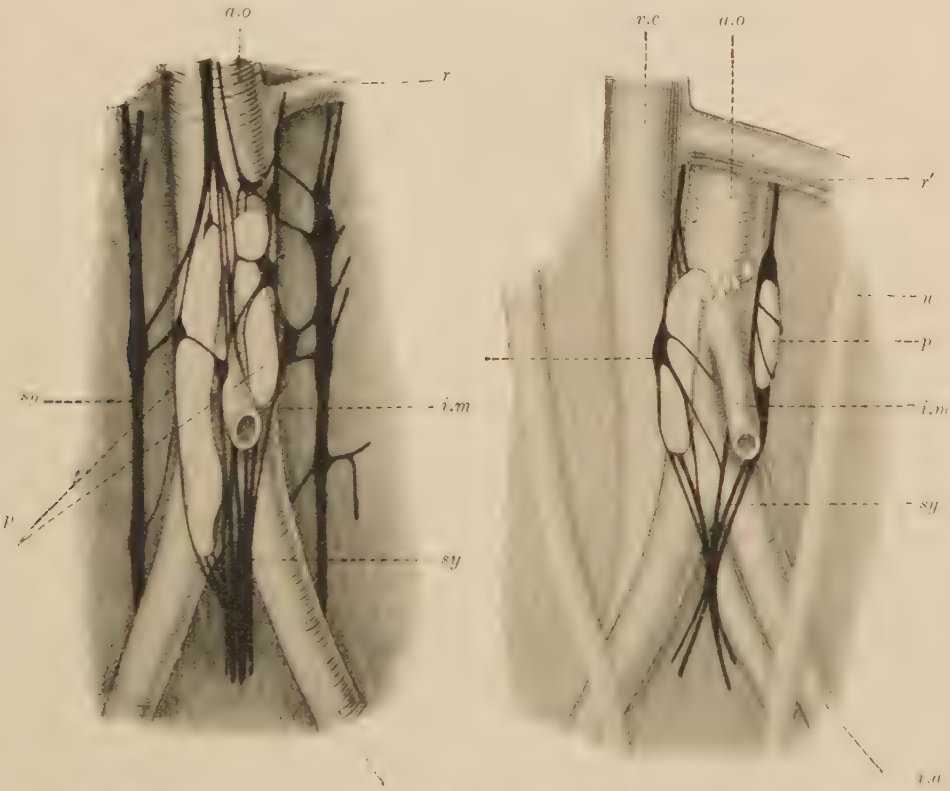


FIG. 305.—DISSECTIONS OF TWO SPECIMENS OF THE LOWER END OF THE AORTA AND ADJACENT STRUCTURES IN THE HUMAN FETUS, TO SHOW THE PARAGANGLIA USUALLY PRESENT IN THAT SITUATION. (Zuckerkandl.)

a.o, abdominal aorta; *v.c*, inferior vena cava; *r*, *r'*, left renal artery and vein respectively; *u*, left ureter; *i.m*, inferior mesenteric artery; *sy*, *sy*, sympathetic trunk and plexus; *p*, paraganglia; *i.a*, iliac artery.

and, like the medulla of the suprarenal glands, contain a number of chromaphil cells. The glands belonging to this group are the aortic, the carotid, the cardiac, and numerous minute chromaphil bodies lying in depressions on the median or dorsal side of the ganglia of the sympathetic trunk. In all probability they

all serve as organs of internal secretion, and form a substance which produces contraction of the non-striped musculature.

The **aortic glands** are the largest. They form a pair of bodies situated in front or at the sides of the abdominal aorta in close relation with the pre-vertebral sympathetic plexuses, and they may extend from the origin of the superior mesenteric or renal arteries to below the bifurcation of the aorta (fig. 305). E. Zuckerkandl[1] gives the average length of the right one in newly born children as 11·6 mm., and that of the left one 8·8 mm. The two main bodies

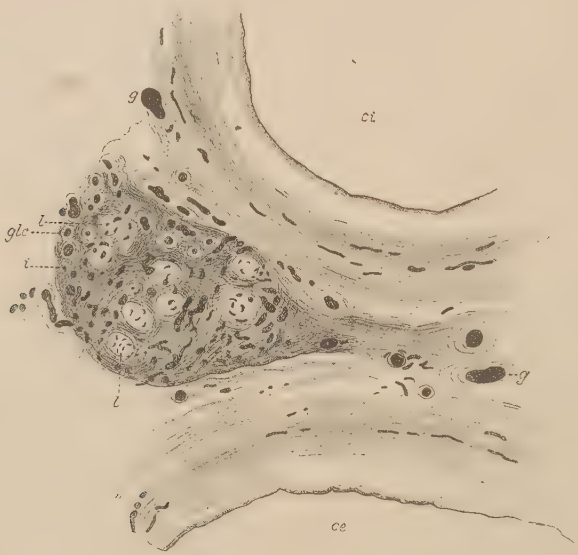


Fig. 306.—Section of the glomus caroticum, just above the bifurcation of the common carotid artery. Somewhat magnified. (Marchand.)

ci, ce, internal and external carotid arteries cut across; *glc,* carotid gland; *g,* blood-vessels; *i,* interstitial connective tissue of gland; *l,* glandular lobules or nodules.

may be united by an isthmus. Continuous with this isthmus, or quite isolated, are masses of chromaphil cells, placed on the cœliac or renal plexus. On the caudal side of the aortic glands there are usually four chromaphil bodies, situated on the hypogastric plexus. The aortic group of chromaphil bodies tends to degenerate after birth. They have been described in children up to eight years of age (Pende); but, according to Zuckerkandl, cannot be recognised by the naked eye in adults, although traces of their peculiar tissue may be detected on microscopic examination.

Blood-vessels.—The aortic bodies are supplied by numerous minute arteries derived from the abdominal aorta, inferior mesenteric, internal spermatic, middle colic, and common iliacs.[2]

The **glomus caroticum** or **carotid gland** (fig. 306), is situated behind the bifurcation of the common carotid artery, and lies in close contact with the wall of the vessel. Its long axis, which is vertical, measures about 5 mm., its breadth is 2·5 mm. to 4 mm., and its thickness 1·5 mm. The gland may be subdivided into two or more lobes, and its fibrous capsule is more or less firmly adherent to the wall of the carotid artery. Some, at least, of its cells give the chromic reaction.

[1] 'Ueber Nebenorgane des Sympathicus im Retroperitonaealraum des Menschen,' *Verhandl. d. anat. Gesellsch.*, Bonn, 1901.

[2] Sperino e Balli, 'La circulazione dell' organo parasympatica della Zuckerkandl nell' nomo,' *Mem. Ph. Accad. Sc. Lett. ed. Arti Modena*, ser. 3, vol. viii., 1909.

It is very vascular, numerous minute arteries passing to it from the carotids, and between these vessels and the veins, there is a sinusoid arrangement of capillaries. Various theories have been advanced with regard to its origin; but whether it is developed directly or indirectly from the epithelium of one of the branchial clefts, or in association with the sympathetic ganglia, is not known.

The cardiac gland.—Wiesel and Weissner[1] found a cylindrical mass embedded in the fatty tissue investing the trunk of the left coronary artery where this vessel was overlapped by the left auricular appendix. It was about 15 mm.

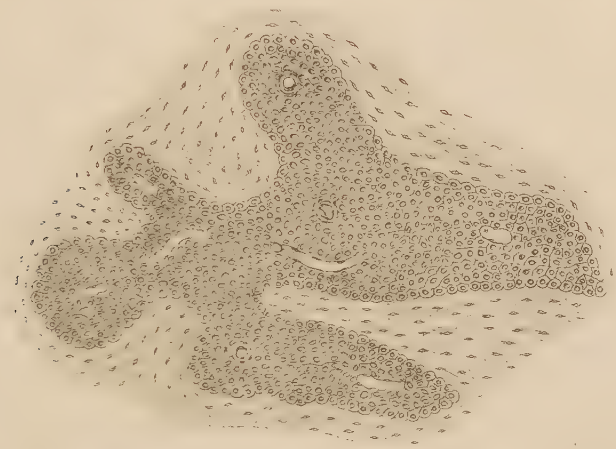


FIG. 307.—SECTION OF AN IRREGULAR NODULE OF THE COCCYGEAL GLAND. Magnified 85 diameters. (Sertoli.)

The section shows the fibrous covering of the nodule, the blood-vessels within it, and the polyhedral cells of which it is constituted.

long and 3 mm. broad, and contained chromaphil cells. Small scattered collections of similar cells have also been described as situated under the pericardium.

The **glomus coccygeum** (*glandula coccygea*, Luschka) is a small organ at most 2·5 mm. in diameter, sometimes broken up into from three to six smaller corpuscles, placed immediately in front of the apex of the coccyx and connected with some of the terminal branches of the middle sacral artery. J. W. Thomson Walker[2] showed by a reconstruction of a series of sections that it consisted of a main mass and a considerable number of minute accessory bodies.

Structure.—It is composed of masses of epithelial cells embedded in a fibrous stroma. These cells have been described as chromaphil; but this is denied by several recent investigators. The glomus is very vascular, and the arteries terminate in sinusoids.

[1] Quoted by Lucien et Parisot, *Glandes surrénales et organes chromaffines*, Paris, 1913.
[2] 'Ueber die menschlichen Steissdrüse,' *Arch. f. microsc. Anatomie*, Bd. lxiv., 1904.

PERITONEUM.

P. T. CRYMBLE.

THE abdominal viscera having been described, as well as the disposition of the peritoneum in relation to each of them, it remains to give an account of that membrane in its whole extent, to trace its continuity over the various parts which it lines or covers, and to describe the cavity it encloses.

The peritoneum lines the whole of the anterior abdominal wall, except along a narrow line extending from the umbilicus upwards to the diaphragm, and corresponding to the interval between the two layers of the falciform ligament of the liver. This peritoneal fold is usually attached to the abdominal wall, slightly to the right of the median plane. For a short distance above the pubes, the peritoneum is loosely connected with the abdominal wall, so that when the bladder becomes distended with urine the serous membrane is detached from the lower part of the abdominal wall. This, however, can only occur to a limited extent, since the peritoneum as it passes upwards towards the umbilicus becomes gradually more firmly adherent to the abdominal wall In cases of great distension of the bladder, an area above the pubic symphysis, 3 cm. in vertical extent, may be uncovered by peritoneum.

Between the anterior wall of the pelvis and the umbilicus, the peritoneum is raised into five vertical folds, with intervening depressions, by certain structures which converge towards the umbilicus. These folds are a median one (plica umbilicalis media), caused by the urachus, and two lateral, on each side, formed by the ligamentum umbilicale laterale (plica umbilicalis lateralis), and the inferior epigastric artery (plica epigastrica) (see fig. 308).

By means of these folds, three fossæ are mapped out on each side of the middle line above the inguinal ligament: they are termed the supravesical, the median, and the lateral inguinal fossæ.

After lining the anterior wall of the abdomen, the peritoneum passes round on each side of the lumbar and iliac regions, where it meets with the right and left portions of the large intestine. On the right side, it completely invests the cæcum and its vermiform appendix, and it also provides the latter with a mesentery. Higher up, it covers the ascending colon in front and on the outer side, the remaining part of the circumference of the bowel being usually uncovered.

Leaping the right colon, the peritoneum gives a scanty covering to the lower part of the anterior surface of the right kidney and adjoining *pars duodeni descendens* where that intestine comes down from behind the transverse mesocolon; lower down, it continues over muscles and vessels to the root of the mesentery, proceeds forwards to form the right layer of that fold, passes round the jejunum and ileum, affording them their peritoneal coat, and returns back to the posterior abdominal wall, thus completing the mesentery on the left side. The membrane now passes in front of the lower portion of the left kidney to the descending colon, which it invests much in the same manner as the ascending, and is then continued over the lateral wall on the left side to the front again, thus completing a horizontal circuit round

the abdomen. Although the descending colon is usually uncovered behind and on its inner side, yet occasionally it is entirely invested by peritoneum and provided with a meso-colon. The frequency, however, with which a descending meso-colon occurs has been much exaggerated.

The iliac colon is, as a rule, devoid of a mesentery; but, occasionally, the lower third possesses a mesentery in common with the pelvic colon. The pelvic meso-

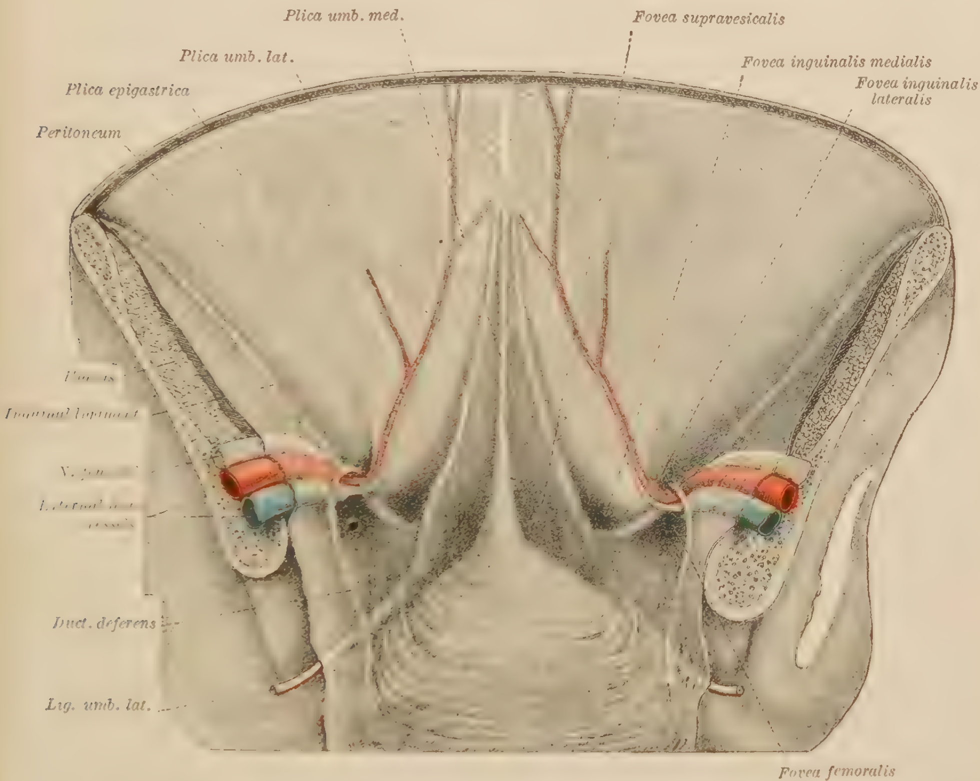


FIG. 308—VIEW FROM BEHIND OF THE LOWER PART OF THE ANTERIOR ABDOMINAL WALL AND OF THE BLADDER. (G. D. Thane, after Joessel.)

colon is attached along the left pelvic brim from a point 3 cm. to 5 cm. above the inguinal ligament to the bifurcation of the left common iliac artery; whence the line of attachment extends downwards and inwards to the second or third sacral vertebra, where the peritoneum passes on to the rectum, covering this portion of the intestine at first in front and at the side, then in front only from which surface it is reflected on to the bladder in the male, forming here the *recto-vesical pouch*.

When the bladder is contracted, this pouch is partially subdivided into anterior and posterior portions by a coronally placed peritoneal fold which encloses laterally the ductus deferentes, and has been described as the sacro-genital fold [1] (fig. 231).

From the apex of the bladder, the peritoneum passes on to the urachus, as already described. In the female, the peritoneum passes from the rectum to the upper part of the vagina, and over the posterior surface, the fundus, and the upper part of the anterior surface of the uterus, whence it goes to the bladder. The

[1] A. F. Dixon, 'The Form of the Empty Bladder,' &c., *Jour. Anat. and Phys.*, vol. xxxiv., January 1900.

uterine peritoneum extends laterally to form the broad ligaments of the uterus, along the upper border of which the uterine tubes receive from it a serous covering; at their fimbriated openings, the peritoneum is continuous with the mucous membrane lining the tubes.

The uterus and its broad ligaments subdivide the female pelvic cavity into an anterior or vesico-uterine excavation and a posterior or recto-uterine excavation. Two semilunar folds of peritoneum, covering the anterior portions of the utero-sacral ligaments may divide this latter space into a median and two lateral portions.

The peritoneum, on being traced upwards on the anterior wall, is found to line the vault of the diaphragm, adhering moderately to the muscular and firmly to the tendinous part, and continuing down behind as far as the posterior surface of the liver. It then passes forwards on to the liver, forming the falciform, coronary, and triangular ligaments of that organ, already specially described.

After crossing the upper and anterior surfaces of the liver, it turns backwards on the under surface; but, after covering the quadrate lobe, and arriving at the porta hepatis, it meets with a peritoneal layer from behind, and in association with it, stretches from the liver to the stomach, to form the lesser omentum, as will be presently explained. To the right of this part, it invests the gall-bladder, more or less completely, and the under-surface of the right lobe of the liver, covers anteriorly the adjacent part of the duodenum, and passes to the upper end of the right kidney, forming here a slight fold, named *hepato-renal ligament*. It descends in front of the hepatic flexure of the colon and reaches the right colon, on which it has been already traced. To the left of the fossa of the umbilical vein, the peritoneum invests the whole of the left lobe of the liver, and stretches out as the long, left triangular ligament, anterior and lateral to the œsophageal opening. It then passes down over that opening and covers the front and left side of the gullet, spreads over the left end of the stomach, where it passes off to invest the spleen, forming a duplicature, named the *gastro-splenic ligament*. When the membrane passes from the diaphragm to the stomach it forms a small duplicature to the left of the œsophagus, named the *gastro-phrenic ligament*; it extends also as a generally stout and well-marked fold (the *costo-* or *phreno-colic ligament*) from the diaphragm opposite the tenth and eleventh ribs to the splenic flexure of the colon, then passes over the splenic flexure, and reaches the left kidney and descending colon, where it has been already described.

Omenta.—The arrangement of the remaining part of the peritoneum—that between the stomach, liver, and transverse colon—is somewhat complex, in consequence of the membrane forming in this situation a second and smaller sac, which communicates towards the right with the general cavity by a narrow throat, named the *foramen epiploicum* [*Winslowi*]. This passage, which admits one or two fingers, is situated behind the bundle of hepatic vessels, which stretches between the liver and the duodenum; behind the orifice is the inferior vena cava; above, is the caudate process of the liver; and its lower boundary is formed by the duodenum and a curve of the hepatic artery. From this opening the lesser sac spreads out to the left, behind the general or main sac of the peritoneum. It covers a part of the posterior abdominal wall; but in front and below it is applied to the back of the main sac, to which it adheres except where the stomach and first part of duodenum are interposed. Moreover, it indents, as it were, the back of the main sac, and between the stomach and colon protudes into it in the form of a great pouch—the bag of the omentum—which thus has a double coat, formed by the apposition of the membranes of both sacs. To trace this arrangement more particularly: suppose a finger pushed into the foramen of Winslow, and the thumb brought to meet it from before, to the left of the hepatic vessels; the membrane held between is double; its anterior layer (from the greater sac) turns round the hepatic vessels into the foramen, and then belongs to the lesser

sac. The double membrane, so constituted, is the *small omentum*. From the point indicated, it may be followed to the porta hepatis of the liver, where its laminæ separate; the anterior, which has already been traced from above, spreading on the adjacent part of the liver; the posterior covering the caudate lobe, where it will be again met with. The attachment of the combined layers continues backwards from the left end of the porta hepatis along the fossa of the ductus venosus to the diaphragm on which it runs a short way to reach the œsophagus, where the anterior lamina covers the end of that tube in front and on the left, and the posterior lamina invests it on the right and behind. From this point, as far as the pylorus, the small omentum is attached to the lesser curvature of the stomach, where its laminæ separate—one covering the anterior and the other the posterior surface of the organ; but, meeting again at the great curvature, they pass down in conjunction to a variable distance in front of the small intestine to form the anterior wall of the bursa omenti majoris, and then turn up to form its posterior wall. Meeting next with the transverse colon, the two laminæ separate, and enclose that intestine, but meet again behind it to form the transverse meso-colon. This extends back to the anterior border of the pancreas, from which its inferior layer passes backwards over the inferior surface of this organ, and then turns downwards over the posterior wall of the abdomen, and forms the mesentery, where it has been already recognised. The superior layer, on the other hand—which, as will be understood, belongs to the lesser sac—covers the front of the pancreas, the cœliac artery and its main divisions, the upper part of the left kidney, and the portion of the diaphragm between the aortic and caval orifices, and may extend to the left end of the pancreas and gastric surface of the spleen, partially investing the latter organ and forming part of the gastro-splenic ligament. It then goes forward on the caudate lobe to the porta hepatis and the line of attachment of the lesser omentum, of which it then becomes the posterior layer. More to the right, the layer in question passes over the vena cava, and continues into the general peritoneum beyond the foramen of Winslow.

From the description given, it will be understood that, as the walls of the bursa omenti majoris consist of two peritoneal layers, the whole thickness of the great omentum will comprise four layers: but although the cavity may be inflated in its whole extent in the infantile body, its walls afterwards cohere, and it becomes impervious in its lower part. Fat, moreover, accumulates between its laminæ; long slender branches also pass down into it from the gastro-epiploic vessels.

The part of the membrane just described, which is attached to the great curvature of the stomach and transverse colon, and which is continuous with the gastro-splenic ligament, is usually named the *great omentum*. The great omentum usually reaches lower down at its left border, and it is said that omental inguinal herniæ are more common on the left side.

The description now given of the relation of the omentum to the meso-colon agrees with the appearances most frequently seen in the adult subject, the exterior (here also posterior) layer of the great omentum being described as separating from the layer within, belonging to the bursa omenti majoris, when it reaches the transverse colon so as to pass behind or below that viscus, and as proceeding thence backwards to the abdominal wall as the posterior or lower layer of the transverse meso-colon. In the young fetus, however, two layers of peritoneum pass from the greater curvature of the stomach, upwards and backwards, to the posterior abdominal wall, forming the dorsal meso-gastrium; and the transverse colon possesses an independent meso-colon. Subsequently, the posterior layer of the meso-gastrium fuses with the anterior layer of the transverse meso-colon. Occasionally, in the child, and even in the adult, these layers remain distinct.

CAVUM PERITONÆI.

The **great sac** possesses such an extensive and complicated cavity that it is necessary in a description to subdivide it, and certain features of its shape and relations have been utilised for this purpose. Thus the transverse meso-colon forms a fairly efficient barrier between the sub-phrenic region and the ilio-lumbar region, and the ilio-lumbar region is divided into a right and a left portion by the attachment of the mesentery. The brim of the true pelvis, although not forming a barrier, is a definite threshold between the ilio-lumbar and a pelvic region.

THE SUB-PHRENIC REGION.

The **sub-phrenic** region is bounded above by the diaphragm, and is limited inferiorly by the transverse meso-colon, the phrenico-colic ligament, and the sustentaculum hepatis, when present. It is related to the liver, the spleen, the

FIG. 309.—HORIZONTAL SECTION OF A MAN, AGED FIFTY YEARS. (P. T. Crymble.)
The gastric and superior recesses of the lesser sac and the sub-phrenic region of the great sac are exposed.

upper poles of the two kidneys, the suprarenal glands, the stomach, the pancreas, and the first few inches of the duodenum.

H. Barnard ('British Medical Journal,' February 15, 1908) divides the sub-phrenic region into six spaces :—

A. Intraperitoneal :

a. Right { 1. Anterior. 2. Posterior.

b. Left { 3. Anterior. 4. Posterior.

B. Extraperitoneal :

5. Right.
6. Left.

The four intraperitoneal spaces are formed by the cruciform arrangement of the ligaments of the liver—namely, the coronary, the falciform, and the right and left triangular ligaments.

The right extraperitoneal space is between the layers of the coronary ligament, and the left extraperitoneal space is round the upper pole of the left kidney.

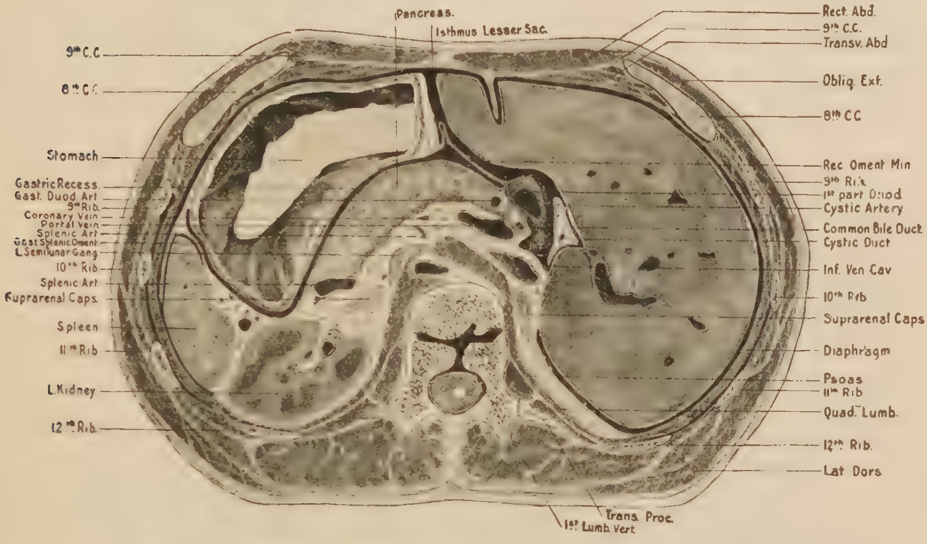


FIG. 310.—HORIZONTAL SECTION OF A MAN, AGED FIFTY YEARS. (P. T. Crymble.)
Illustrates the gastric recess of the lesser sac and the sub-phrenic region of the great sac.

The left posterior intraperitoneal space corresponds to the upper portion of the lesser sac, and will be described later.

FIG. 311.—HORIZONTAL SECTION OF A MAN, AGED FIFTY YEARS. (P. T. Crymble.)
Illustrates the gastric recess of the lesser sac, the sub-phrenic region, and the highest part of the left ilio-lumbar region of the great sac. The presence of a costo-gastric ligament and the relation of the pancreas to the eleventh left rib are somewhat abnormal.

The remaining three spaces, *i.e.* the right anterior and posterior intraperitoneal and the left anterior intraperitoneal, will be now fully described.

The **right anterior intraperitoneal space** intervenes between the right lobe of the liver and the diaphragm: medially, it is limited by the falciform ligament; posteriorly, by the superior layer of the coronary and by the right triangular ligament; and inferiorly, by the sharp inferior margin of the liver. Around the free edge of the right triangular ligament, and around the inferior margin of the liver, it communicates with the right posterior intraperitoneal space; but when the peritoneum of this region is inflamed, adhesions between the liver and the diaphragm,

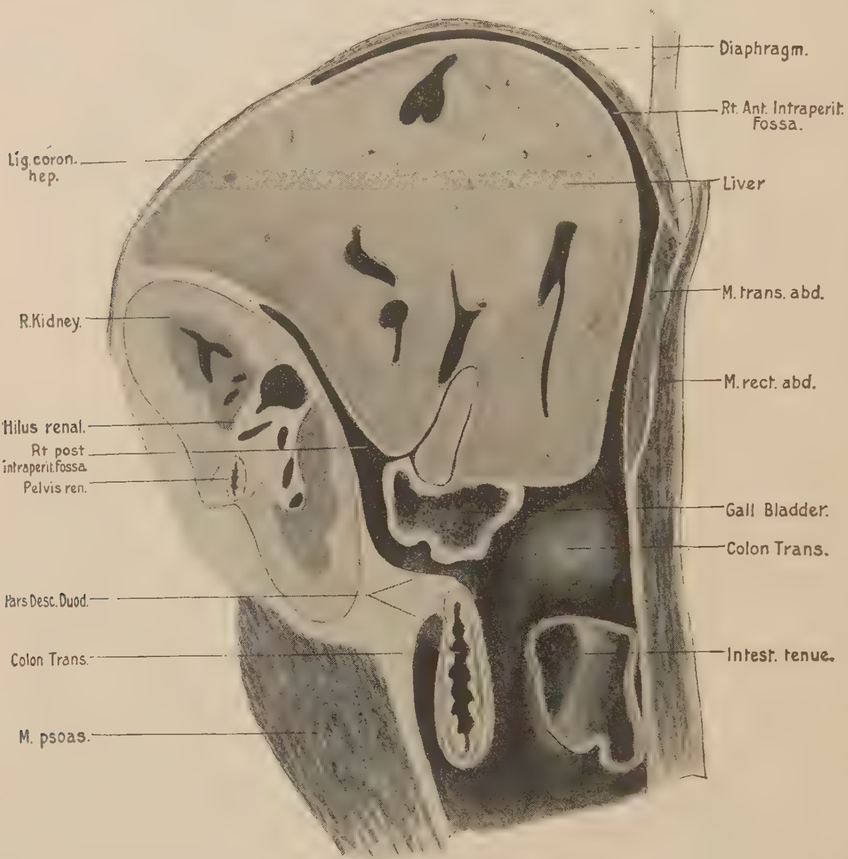


Fig. 312.—A sagittal section through the right lateral line, showing the right anterior and posterior intraperitoneal spaces. (P. T. Crymble.)

The transverse meso-colon is seen separating the right posterior intraperitoneal or sub-hepatic space from the right ilio-lumbar region. The viscera in relation to the sub-hepatic space are the liver, the right kidney, the gall-bladder, the pars descendens duodeni, and the transverse colon.

or between the liver and the transverse colon, may obliterate this communication. The relations of this space are illustrated in the horizontal sections (figs. 309, 310, 311), and in the sagittal section (fig. 312).

The **right posterior intraperitoneal space**, or sub-hepatic space, lies between the inferior surface of the liver and the right kidney, and contains the gall-bladder and first few inches of the duodenum. Superiorly, it is limited by the right triangular ligament and by the posterior layer of the coronary ligament; inferiorly, it extends to the hepatic flexure and the transverse colon; laterally, it communicates freely with the right anterior intraperitoneal space, and, medially, it communicates with the lesser sac through the foramen of Winslow. Anterior to

this foramen, it passes freely into the space between the lesser omentum and the left lobe of the liver. These relations are illustrated in figs. 312 and 320.

The **left anterior intraperitoneal space** contains the left lobe of the liver, the anterior surface and fundus of the stomach, and the spleen. It is a very irregular space, limited medially by the falciform ligament; postero-inferiorly, by the lieno-renal ligament; infero-laterally, by the splenic flexure and the phrenico-colic ligament; whilst, antero-inferiorly, it communicates with the sub-hepatic

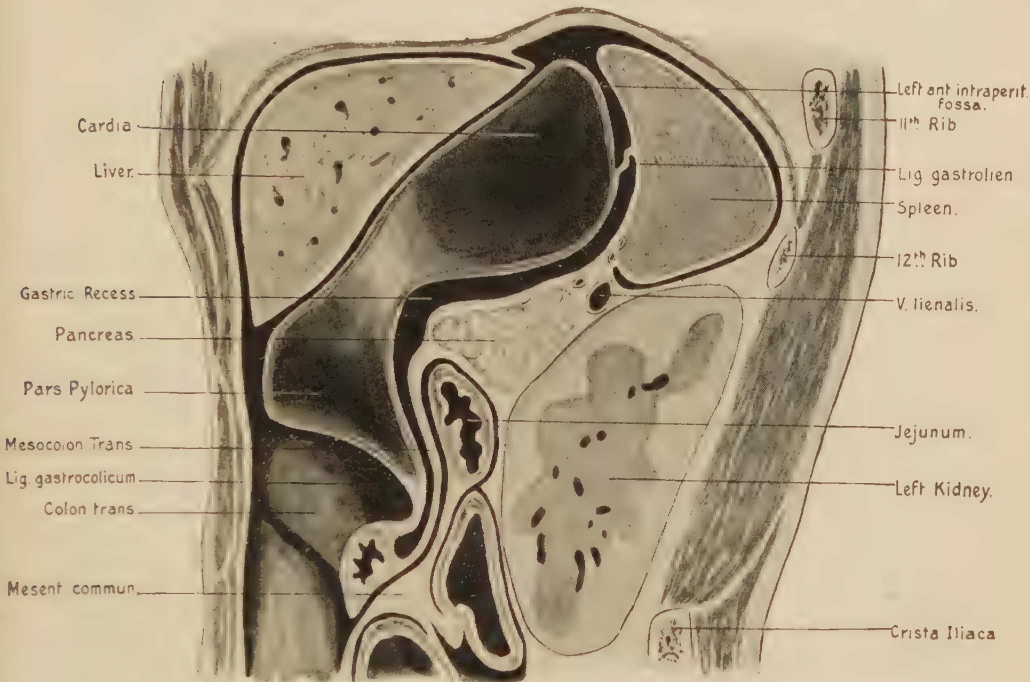


FIG. 313.—SAGITTAL SECTION THROUGH A PLANE SLIGHTLY MEDIAN TO THE LEFT LATERAL LINE. (P. T. Crymble.)

The gastric recess of the lesser sac, or the left posterior intra-peritoneal space, and the left anterior intra-peritoneal space are exposed. The upper part of the left ilio-lumbar region, containing small intestine, is also seen.

space around the inferior margin of the liver, and passes freely in front of the transverse colon into the left ilio-lumbar region. The relations and shape of this space will be most easily studied by reference to the sagittal section (fig. 313), and to the horizontal sections in (figs. 309, 310, and 311).

THE ILIO-LUMBAR REGION.

The **ilio-lumbar region** of the great sac is limited above by the attachment of the transverse meso-colon to the duodenum and pancreas. Lateral to the hepatic flexure of the colon, there is a free communication with the sub-phrenic region, except in the presence of a sustentaculum hepatis; and lateral to the splenic flexure, the phrenico-colic ligament forms, according to its development, a more or less efficient barrier between it and the left anterior intraperitoneal space. Inferiorly, across the inner margins of the psoas muscles and the sacral promontory, there is free communication with the pelvic cavity; but the pelvic meso-colon on the left and the mesentery on the right form incomplete septa between the two.

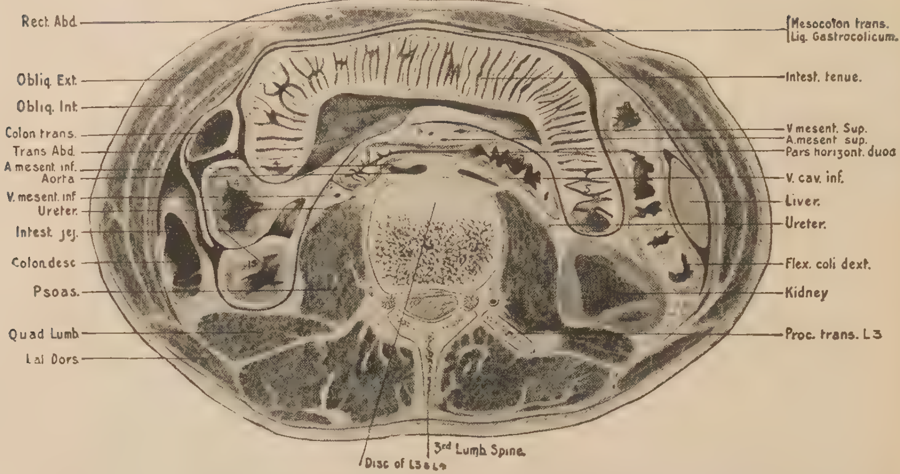


FIG. 314.—HORIZONTAL SECTION OF A MAN, AGED FIFTY YEARS, THROUGH THE ILIO-LUMBAR REGION OF THE GREAT SAC. (P. T. Crymble.)

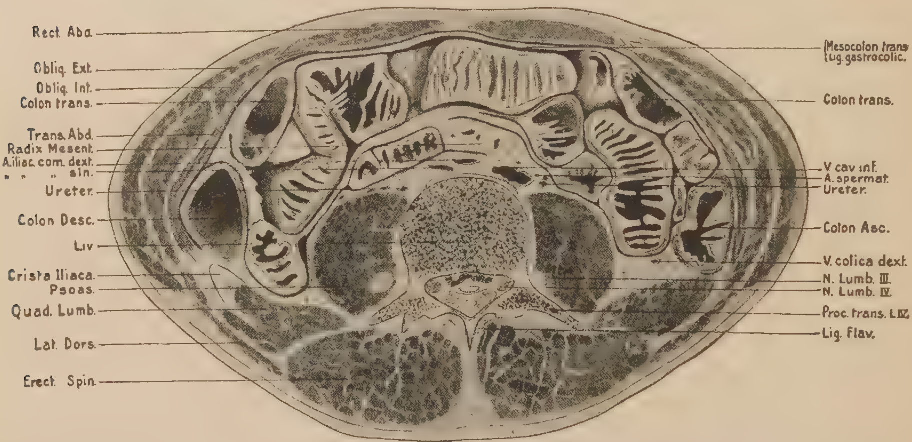


FIG. 315.—HORIZONTAL SECTION OF A MAN, AGED FIFTY YEARS, THROUGH THE ILIO-LUMBAR REGION OF THE GREAT SAC AT THE LEVEL OF THE FOURTH LUMBAR VERTEBRA. (P. T. Crymble.)

FIG. 316.—HORIZONTAL SECTION OF A MAN, AGED FIFTY YEARS, THROUGH THE LOWER PARTS OF THE ILIO-LUMBAR REGIONS AND THE UPPER PART OF THE PELVIC REGION OF THE GREAT SAC. (P. T. Crymble.)

The mesentery of the small intestine divides the space into a right and left portion

The **right ilio-lumbar region** is limited medially by the attachment of the mesentery, superiorly by the transverse meso-colon, and inferiorly by the inner margin of the psoas. Viewed from the front, it is somewhat triangular in shape, the three sides of the triangle being formed by (*a*) the lateral abdominal wall and iliac crest, (*b*) the transverse meso-colon, and (*c*) the mesentery attachment and the inner margin of the psoas. Its contents are the cæcum and vermiform appendix, the ascending colon, the first few inches of the transverse colon, the lower portion of the pars descendens duodeni, a portion of the head of the pancreas, and, at times, some inches of small intestine. The relation of small intestine to this region is very variable, and depends upon several factors. In the fetus, owing to the small size of the pelvic cavity, a considerable length of small intestine occupies

FIG. 317.—HORIZONTAL SECTION OF A MAN, AGED FIFTY YEARS, THROUGH THE UPPER PART OF THE LEFT ILIO-LUMBAR REGION OF THE GREAT SAC. (P. T. Crymble.)

At this level the contents of the region are coils of jejunum, and entering into its walls are the pars ascendens duodeni, the lower pole of the left kidney, and the splenic flexure of the colon. Anteriorly, it is bounded by the transverse meso-colon.

this region. Distension of pelvic viscera or fixation of the transverse colon in the left ilio-lumbar region, forces the jejunum from its normal position into the right ilio-lumbar space. On the other hand, the usual distended condition of the cæcum, ascending colon, and first third of the transverse colon, accounts for either the normal absence of small intestine or the presence of only a few inches in this region.

In the horizontal section (fig. 314), the most superior part of this space is seen, and is occupied by a portion of transverse colon, a few inches of jejunum, and the horizontal portion of the duodenum.

In the horizontal section (fig. 315), its contents are the ascending colon and loops of small intestine; and in the section (fig. 316) through the lower part of the space, the cæcum and terminal portion of the ileum are displayed.

The **left ilio-lumbar region** extends to a higher level than the right ilio-lumbar region. Thus it is present in the horizontal sections through the second and upper part of the third lumbar vertebræ (see figs. 311, 317), whereas the

right space is entirely inferior to this level. Owing to the obliquity of the mesenteric attachment, this left space widens out inferiorly, and is therefore more extensive than the right space. Superiorly, it surrounds the duodeno-jejunal flexure, and is limited by the transverse meso-colon. Inferiorly, it communicates with the pelvic cavity across the pelvic brim; but the attachment of the pelvic meso-colon to the psoas margin partially separates the two spaces. Medially, it is limited by the mesenteric attachment, and laterally by the abdominal wall. Its contents are: the distal portion of the transverse colon, the descending and iliac colons, and the main mass of the small intestine. The body of the pancreas and the lower pole of the left kidney project into its upper part (see fig. 313).

THE PELVIC REGION.

This portion of the great sac differs according to the sex, and its contents vary according to the condition of the pelvic viscera. Thus with an empty rectum,

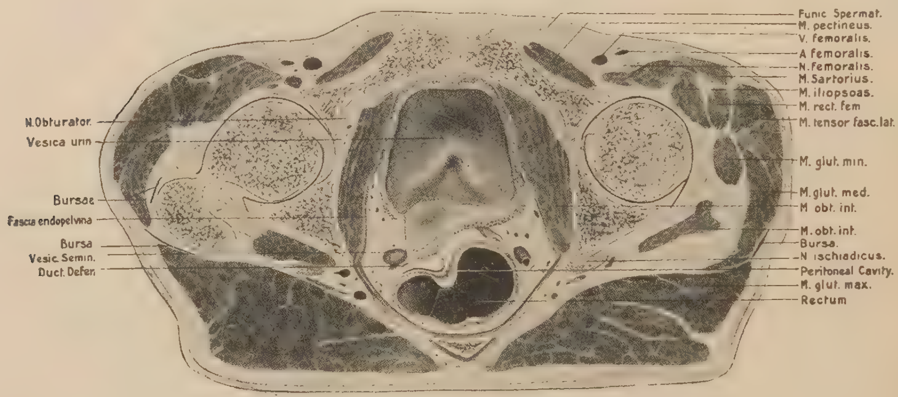


FIG. 318.—HORIZONTAL SECTION OF A MAN, AGED FIFTY YEARS, THROUGH THE LOWEST PART OF THE GREAT SAC. (P. T. Crymble.)

The great sac (peritoneal cavity) is to be seen lying between the left seminal vesicle and the rectum.

bladder, and uterus, a considerable length of small intestine is present, but distension of one or more of these viscera may prevent the entrance of the jejuno-ileum.

In the male, the great sac descends between the rectum and bladder, as the recto-vesical pouch, to the upper ends of the seminal vesicles (see fig. 318). From this point, upwards, the rectum is in relation to the peritoneum; inferiorly the anterior surface, and superiorly the anterior and lateral surfaces, being covered. At the second or third sacral vertebra is situated the junction of the rectum and the pelvic colon. A line drawn from this point to the lower end of the left common iliac artery, and thence along the inner border of the psoas to a point half-way to the inguinal ligament, corresponds to the attachment of the pelvic meso-colon.

Owing to this arrangement of the meso-colon, the ileum tends to occupy the right side of the pelvic space. The pelvic colon may lie entirely within this space, or may form a U-shaped loop and occupy the ilio-lumbar region (see fig. 348).

In the female, the uterus and the broad ligaments form a coronally placed septum across the pelvic cavity, dividing this portion of the great sac into an anterior or utero-vesical pouch and a posterior or utero-rectal pouch (pouch of Douglas). Either of these pouches may contain small intestine, and, in addition, the utero-rectal pouch contains the ovaries and the lateral ends of the uterine tubes.

In the male, the recto-vesical pouch is, in many cases, partially subdivided by a coronally placed fold of peritoneum, which is attached laterally to the ductus deferentes, and may be called a genital fold since it corresponds to the broad ligament in the female. It disappears with distension of the bladder.

THE LESSER SAC (BURSA OMENTALIS).

The **lesser sac** of **peritoneum** is a diverticulum of the main peritoneal cavity, which lies behind the lesser omentum and the stomach, and passes for a

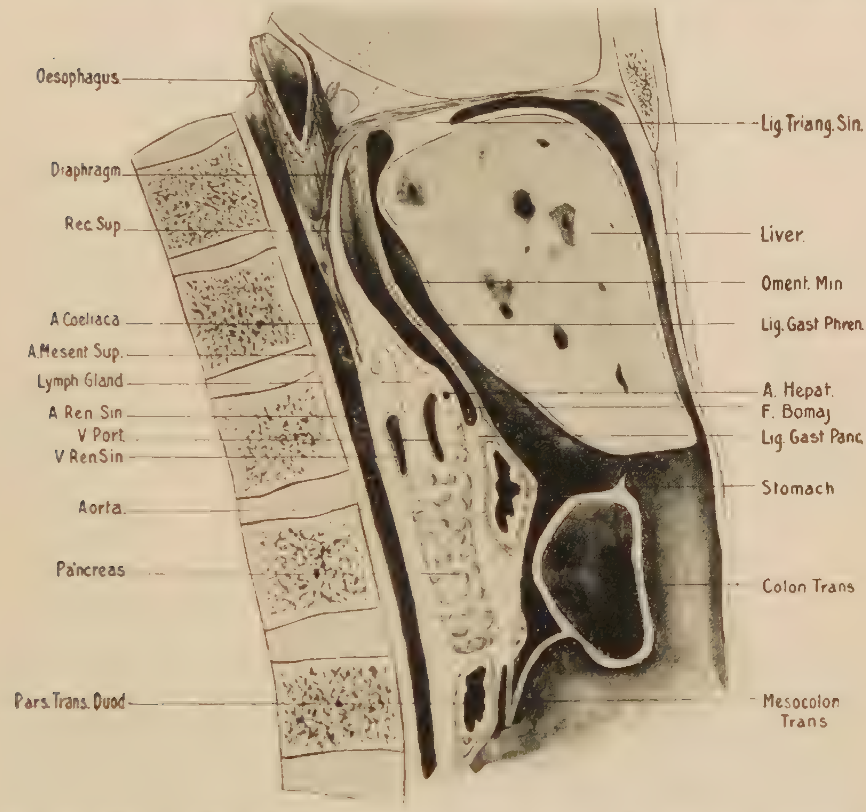


FIG. 319.—MEDIAN SAGITTAL SECTION EXPOSING THE LEFT ANTERIOR INTRAPERITONEAL SPACE AND THE SUPERIOR RECESS OF THE LESSER SAC. (P. T. Crymble.)

variable distance into the great omentum. Its junction with the great sac is called the **foramen epiploicum** or **foramen of Winslow,** and is situated below the caudate process of the liver, above the pars superior duodeni, and in front of the inferior vena cava. The presence of a retro-gastric peritoneal cavity allows the stomach to undergo changes in size and position, and free movement between the lobus caudatus [Spigelii] of the liver and the posterior abdominal wall is facilitated by the extension of the cavity upwards behind the liver (recessus superior). The lesser sac, hour-glass in shape, consists of a superior chamber lying posterior to the gastro-hepatic omentum, and an inferior or retro-gastric chamber.

The **superior chamber**, or **bursa omenti minoris**, communicates with the great sac through the foramen of Winslow, and with the inferior chamber

by an opening, variable in size—the foramen bursæ omenti majoris. It will be described as consisting of three parts :—

1. The vestibule.
2. The superior recess.
3. The middle recess (recessus medius).

The **vestibule** is a narrow passage which passes to the left from the foramen of Winslow, inferior to the processus caudatus of the liver, and superior to the pars superior duodeni and the head of the pancreas. It is bounded in front by that portion of the small omentum which contains the hepatic artery, the common

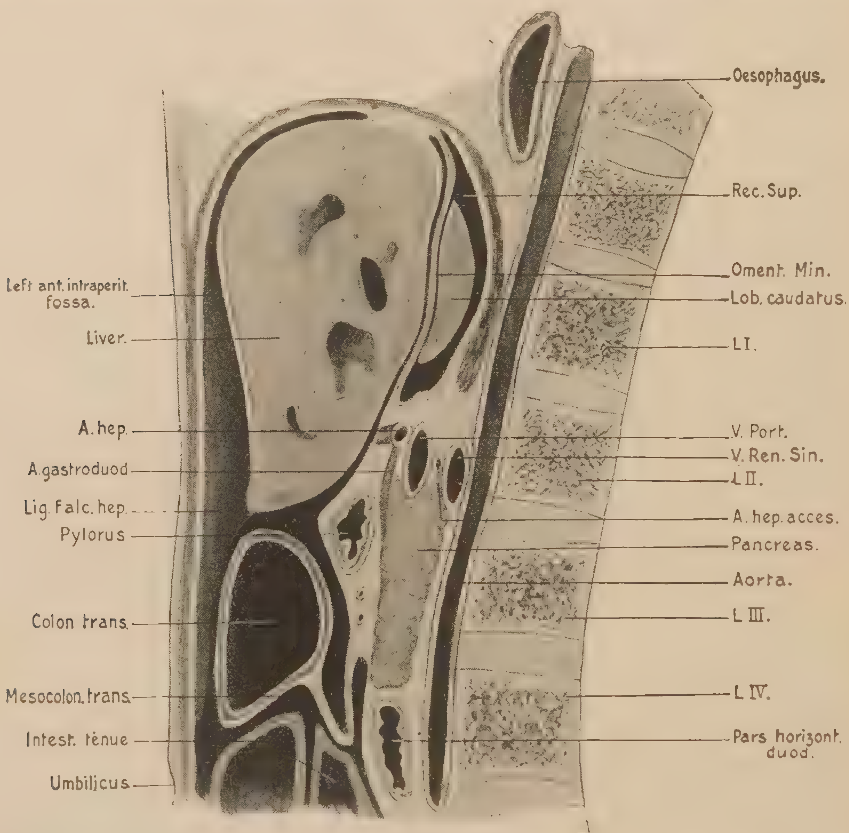


FIG. 320.—MEDIAN SAGITTAL SECTION THROUGH THE LEFT ANTERIOR INTRAPERITONEAL SPACE AND THE SUPERIOR RECESS OF THE LESSER SAC. (P. T. Crymble.)

The viscera occupy a position lower than that usually described: the pylorus lying opposite the disk between the second and third lumbar vertebræ.

bile-duct, and the portal vein; and these vessels are further related to its floor as they pass forwards over the head of the pancreas to enter the two layers of the small omentum.

The **superior recess** is the direct continuation upwards of the vestibule. On horizontal section (fig. 309), it shows a crescent-shaped lumen, the concavity of which is directed to the right, and is produced by the lobus caudatus [Spigelii] of the liver. Anteriorly, and to the left, the space is limited by the small omentum. Posteriorly, it is related to the œsophagus and diaphragm; the aorta, separated by the diaphragm, also forming a close relation with it. Median sagittal sections through the superior recess are illustrated in figs. 319 and 320. The vertical extent and the structures forming the anterior and posterior walls are well seen.

The **recessus medius** varies in size directly with the extent of pancreas in contact with the small omentum. It is a portion of the bursa omenti minoris, which

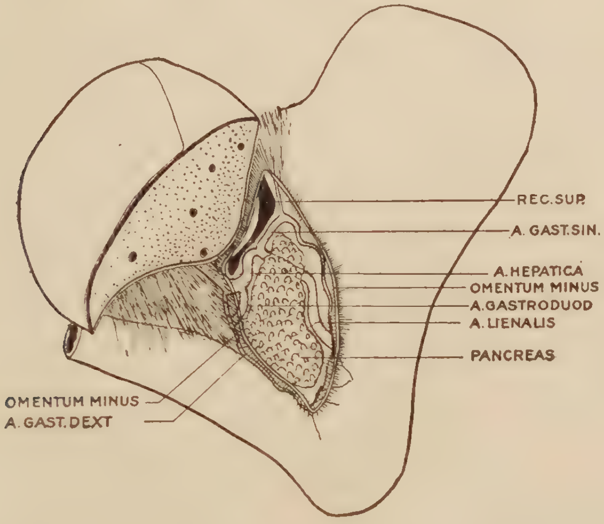


FIG. 321.—DISSECTION TO EXPOSE THE RECESSUS MEDIUS OF THE LESSER SAC. (P. T. Crymble.)

The anterior surface of the stomach and a portion of the right lobe of the liver are illustrated. The stippled region represents the cut surface of the liver. The portion of lesser omentum forming the anterior wall of the recess has been removed to expose the posterior wall formed by the portion of pancreas uncovered by stomach. The recess is very large in this specimen and has no communication with the bursa omenti majoris.

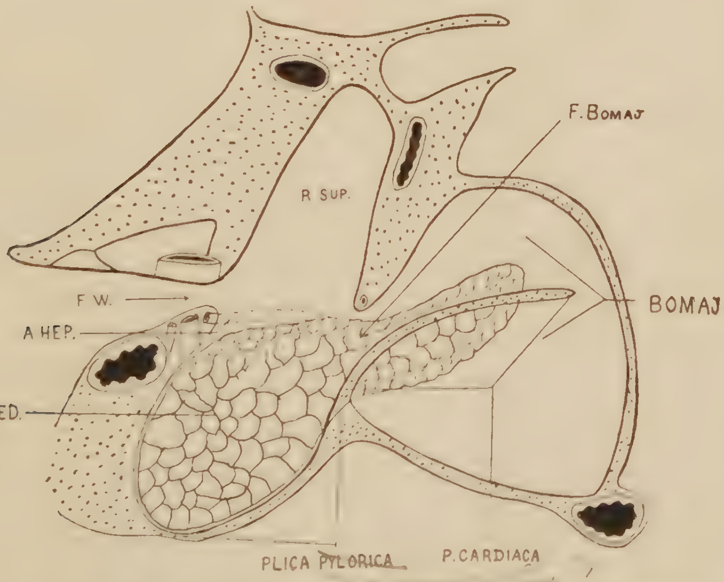


FIG. 322.—ILLUSTRATION OF A DISSECTION OF THE POSTERIOR WALL OF THE LESSER SAC. (P. T. Crymble.)

The stippled area represents the surface uncovered by peritoneum and the serous surface of the pancreas is marked by polygonal areas. There is a large recessus medius and a small foramen (F. BOMAJ) connecting it with the bursa omenti majoris. The bursa omenti majoris is partially subdivided into an upper and a lower part by a horizontal gastro-pancreatic fold (P. CARDIACA) attached to the posterior surface of the cardiac portion of the stomach.

is bounded posteriorly by the pancreas and anteriorly by the lesser omentum. Superiorly, it communicates across the hepatic artery with the superior recess and the vestibule, whilst laterally and inferiorly it is enclosed—except at the foramen

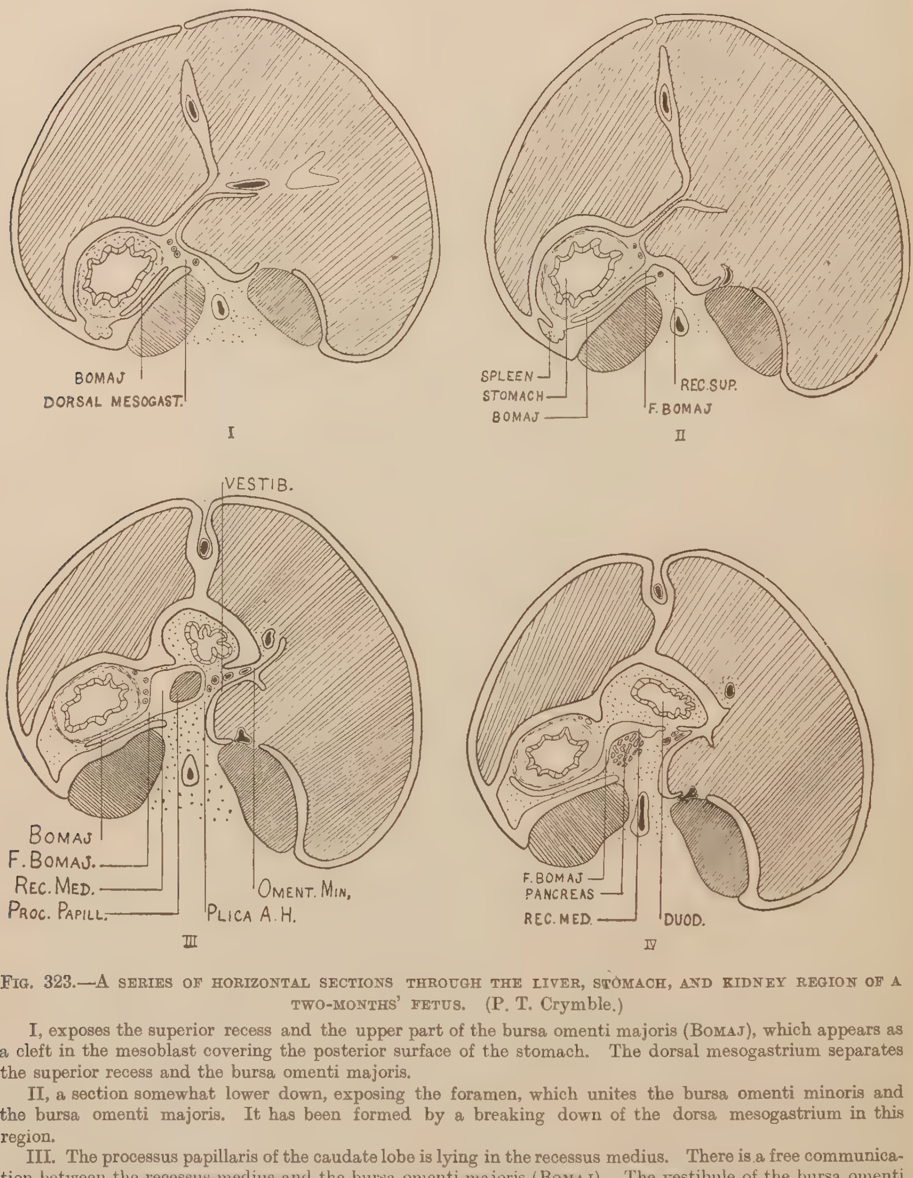


Fig. 323.—A series of horizontal sections through the liver, stomach, and kidney region of a two-months' fetus. (P. T. Crymble.)

I, exposes the superior recess and the upper part of the bursa omenti majoris (Bomaj), which appears as a cleft in the mesoblast covering the posterior surface of the stomach. The dorsal mesogastrium separates the superior recess and the bursa omenti majoris.

II, a section somewhat lower down, exposing the foramen, which unites the bursa omenti minoris and the bursa omenti majoris. It has been formed by a breaking down of the dorsa mesogastrium in this region.

III. The processus papillaris of the caudate lobe is lying in the recessus medius. There is a free communication between the recessus medius and the bursa omenti majoris (Bomaj). The vestibule of the bursa omenti minoris is in this section quite separate from the recessus medius. Superiorly, it is continuous with the superior recess, and communicates with the recessus medius. Inferiorly, it leads to the foramen epiploicum.

IV. The most inferior portion of the recessus medius is exposed. The pancreas forms this portion of its posterior wall.

bursæ omenti majoris—by gastro-pancreatic folds. Its relations and shape may be more easily understood by referring to figs. 321 and 322, where dissections of two large recessi medii are illustrated. In fig. 321, the portion of lesser omentum bounding the recess anteriorly has been removed. The pancreas, the hepatic, left

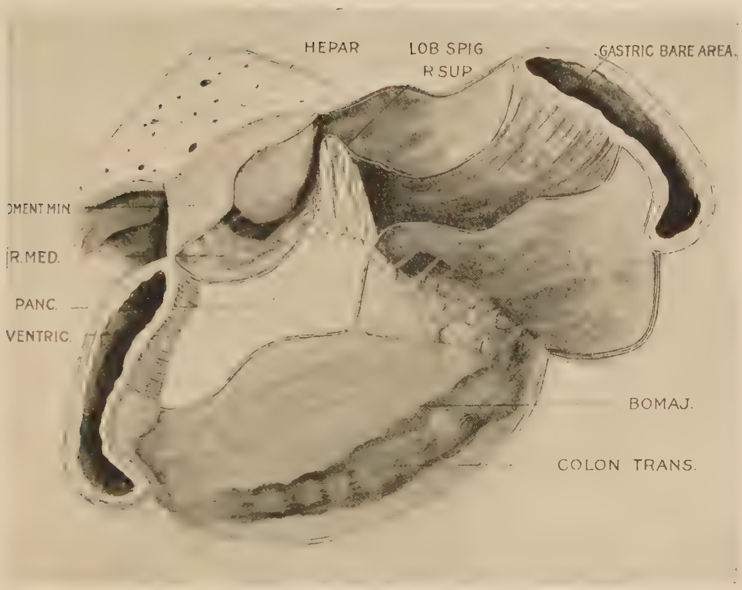


FIG. 324.—A DISSECTION EXPOSING A COMPLETE SEPTUM BURSARUM. (P. T. Crymble.)

The lesser omentum has been divided to display the recessus medius, the superior recess, and the lobus caudatus (Spigelii). Lying behind the recessus medius is a large supra-pancreatic lymph-gland. The recessus medius extends upwards and to the right in front of the hepatic vessels and common bile-duct. An adhesion between the posterior surface of the stomach and the pancreas and diaphragm completely separates the bursa omenti minoris and the bursa omenti majoris. The stomach has been divided, and the cardiac portion turned upwards.

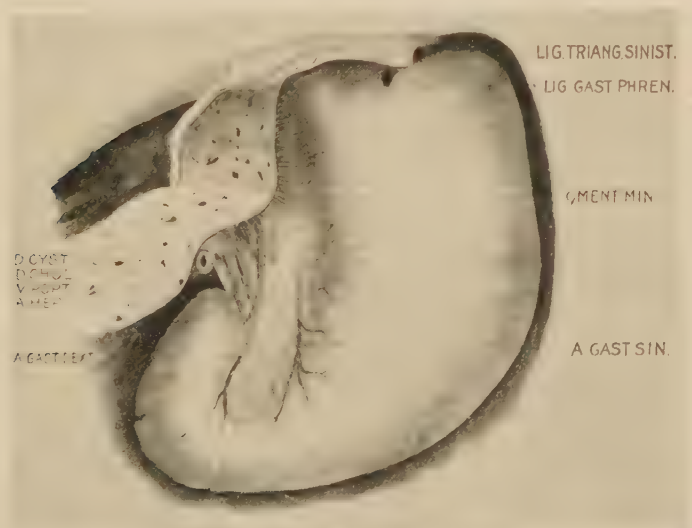


FIG. 325.—DISSECTION OF LESSER SAC, FIRST STAGE. (P. T. Crymble.)

The left lobe and lower part of the right lobe of the liver have been removed in order to expose the lesser omentum. The vessels between the two layers of peritoneum can be seen.

gastric and splenic arteries form its posterior wall, and gastro-pancreatic folds completely enclose it laterally and inferiorly. Superiorly, it communicates freely across the threshold of the hepatic and left gastric arteries with the superior recess and vestibule. There is no foramen communicating with the bursa omenti majoris. Fig. 322 shows another large recessus medius, with a small foramen connecting it with the bursa omenti majoris. The hepatic artery is seen forming the boundary-

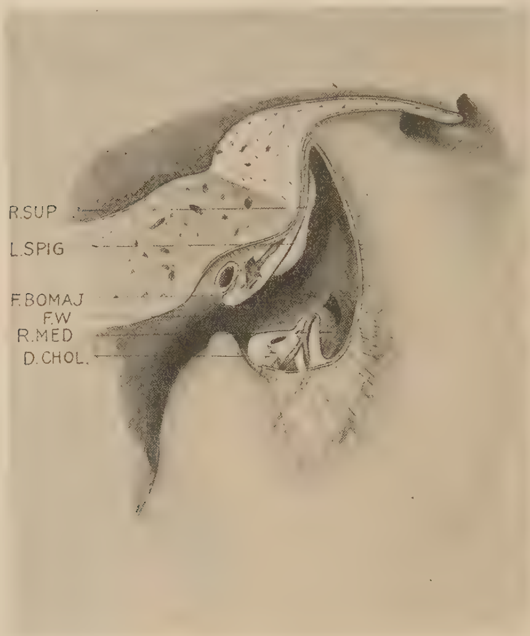


FIG. 326.—DISSECTION OF THE LESSER SAC, SECOND STAGE. (P. T. Crymble.)
The omentum minus has been divided to expose the various parts of the bursa omenti minoris.

line between the recessus medius and the superior recess. In the fetus, the recessus medius is occupied by the processus papillaris of the caudate lobe (fig. 323, III.).

In some cases, this recess is continued upwards and to the right, in front of the hepatic artery, common bile-duct, and portal vein, so as to divide the extreme right portion of the small omentum or the hepato-duodenal ligament into four layers (fig. 324).

The **foramen bursæ omenti majoris** is the communication between the bursa omenti minoris and the bursa omenti majoris. It corresponds to the narrow portion of the hour-glass, and is sometimes referred to as the isthmus of the lesser sac. It varies in size from a minute aperture to an opening admitting five fingers, and rarely, in the presence of a complete septum bursarum, it is absent (figs. 321 and 324).

His (*Arch. f. Anat.*, Ergänzungsband, 1895) defines the position of the foramen by the hepatic and left gastric arteries; but the following objections to this description exist:—

1. When a marked constriction of the lesser sac is present, it is never in the position of the hepatic and left gastric arteries, but always in the plane of the gastro-pancreatic ligaments (fig. 322).

2. When a complete septum bursarum exists, the septum has no relation to the hepatic artery (figs. 321 and 324).

3. Since the recessus medius lies inferior to the hepatic artery, the definition of His would relegate the recess to the bursa omenti majoris, whereas it is in direct relation with the lesser omentum and should therefore be included in the bursa omenti minoris.

The foramen or isthmus will here be described as being bounded by the lesser curvature of the stomach, the pancreas, and the gastro-pancreatic ligaments; or, in those cases where the superior limiting fold springs from the diaphragm, by a gastro-phrenic ligament.

Reference to figs. 322, 326, 327, 328, 329, will make its relations and position clear. Figs. 326 to 329 illustrate a foramen which only admitted a pencil. It is bounded superiorly by a gastro-phrenic ligament, containing in its free border the

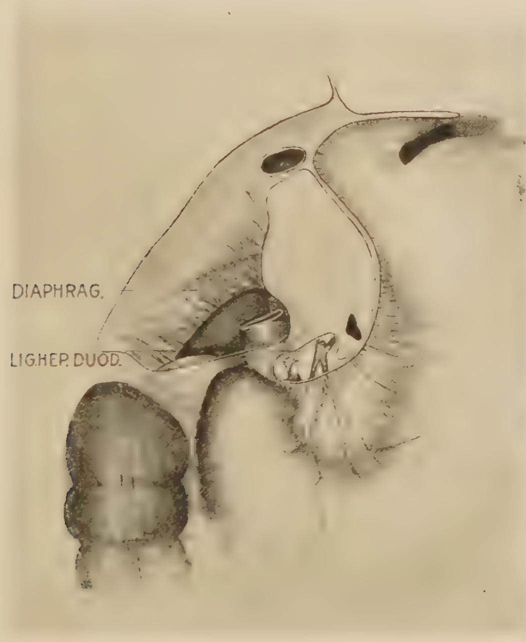


Fig. 327.—Dissection of the lesser sac, third stage. (P. T. Crymble.)

The remaining portion of the liver has been removed, exposing the posterior wall of the superior recess and the posterior relations of the bare area of the liver—*i.e.* the diaphragm, the inferior vena cava, the right suprarenal gland, and the upper pole of the right kidney.

left gastric artery, and it is limited inferiorly by a gastro-pancreatic fold. In this subject the recessus medius was small.

Fig. 322 shows a narrow foramen leading from a large recessus medius into the bursa omenti majoris. Its limiting folds are the same as in the previous case. Figs. 321 and 324 show absence of the foramen, a complete septum bursarum being present. In some cases, the foramen is divided into two apertures by a gastro-pancreatic fold.

The foramen develops as a result of the free movement of the lesser curvature in its immediate neighbourhood. The vertical or cardiac portion of the lesser curvature chiefly experiences lateral movement, and is therefore attached by a hinge-like vertical fold to the diaphragm or diaphragm and pancreas. The horizontal or pyloric portion of the lesser curvature chiefly experiences vertical movement, and is therefore attached by a horizontal fold to the pancreas.

The portion of lesser curvature bounding the foramen shares in both the lateral and vertical movements, and is therefore unattached to the posterior abdominal wall.

The **bursa omenti majoris** lies behind the stomach, and extends for a variable distance into the great omentum. The part in relation to the spleen may be referred to as the splenic recess; the part lying below the level of the foramen as the inferior recess; and the part behind the stomach, which includes the splenic recess and a portion of the inferior recess, as the gastric recess.

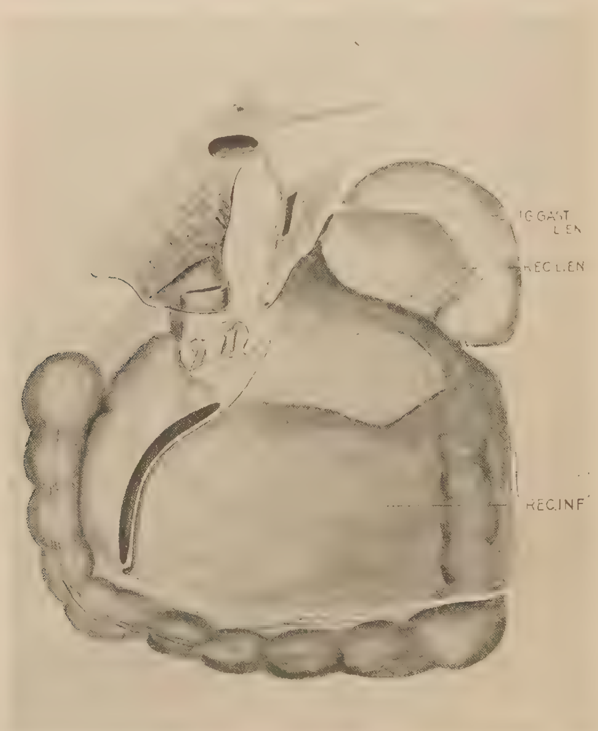


FIG. 328.—DISSECTION OF THE LESSER SAC, FOURTH STAGE. (P. T. Crymble.)

The stomach, with the exception of a part near the pylorus which was adherent to the pancreas, has been removed to expose the splenic and inferior recesses of the bursa omenti majoris.

The **gastric recess** is the result of the changing size and position of the stomach. Its relation and extent are well demonstrated by a series of horizontal sections. In fig. 309 a section at the level of the twelfth thoracic vertebra is shown, and the superior part of the gastric recess is seen, its posterior wall being formed by the left kidney, the lieno-renal ligament, the hilum of the spleen, and the gastro-splenic ligament (omentum). In a section at the level of the first lumbar vertebra (fig. 310), the posterior relations are the pancreas, the left kidney, the spleen, and the gastro-splenic ligament. In a section at the level of the second lumbar vertebra (fig. 311), the pancreas forms the main part of the posterior wall, only a small part of the transverse meso-colon being present at this level. A section through the third lumbar vertebra (fig. 317) demonstrates the transverse meso-colon and the head of the pancreas as the posterior relations.

The gastric recess communicates through the isthmus with the bursa omenti

minoris. Variations in shape and extent of the bursa omenti majoris are common, and depend upon variations in the attachment of the stomach to the pancreas and upon the amount of fusion between the layers of the great omentum. Fig. 322 shows a bursa omenti majoris almost completely subdivided by a horizontal gastro-pancreatic fold into an upper and a lower chamber.

Figs. 325 to 329 illustrate the anatomy of the lesser sac.

In fig. 325, the lesser omentum and the structures contained between its two

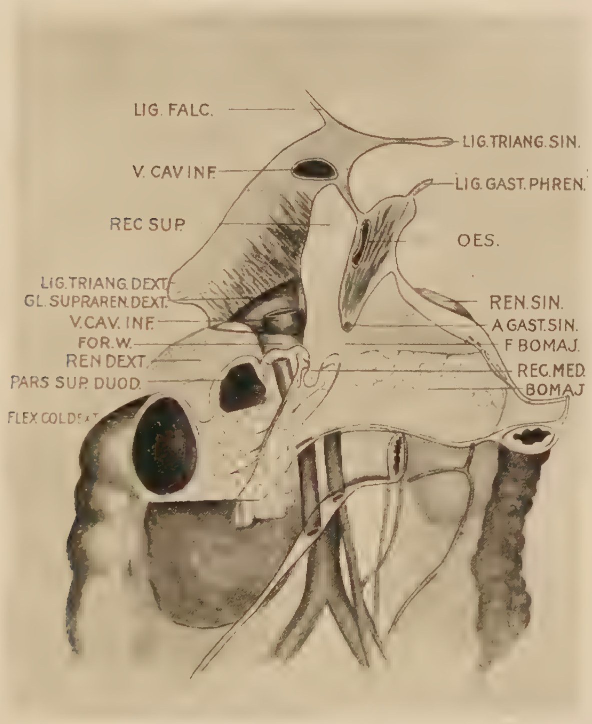


FIG. 329.—FINAL STAGE IN THE DISSECTION OF THE LESSER SAC. (P. T. Crymble.)

The transverse colon and meso-colon, the spleen, the remaining portion of the stomach and the first inch of the duodenum have been removed. The right and left ilio-lumbar regions of the great sac, separated from each other by the mesentery of the small intestine, have been exposed.

layers have been exposed by removing the left lobe and a portion of the right lobe of the liver. In fig. 326, the lesser omentum has been divided to expose:

a. The foramen of Winslow (F.W.), or the right orifice of the vestibule.

b. The vestibule, or that part of the lesser sac lying behind the hepato-duodenal ligament.

c. The superior recess—R.SUP.

d. The recessus medius—R.MED.

e. The foramen bursæ omenti majoris—F.BOMAJ.

The lesser omentum is seen to be attached to the porta hepatis and the fossa ductus venosi of the liver.

In fig. 327, the remaining part of the right lobe of the liver has been removed by dividing the ligamentum triangulare dexter and the ligaments bounding the bare area, and by taking away the upper part of the inferior vena cava.

The posterior wall of the superior recess is well seen. In fig. 328 all the stomach,

with the exception of a part near the pylorus which was closely adherent to the pancreas, has been removed. The following peritoneal folds and structures were divided :—

Anterior and posterior gastro-phrenic ligaments.
Gastro-splenic omentum.
Gastro-colic omentum.
Œsophagus.
Right and left gastric arteries.
Right and left gastro-epiploic arteries.

The foramen or isthmus is here very small, and is bounded superiorly by a gastrophrenic ligament enclosing the left gastric artery, and inferiorly by a gastro-pancreatic ligament. The lateral and vertical extent of the bursa omenti majoris and its splenic and inferior recesses are exposed. Fig. 329 shows the final stage of the dissection. The transverse colon and meso-colon, the spleen, the remaining portion of the stomach, and the first inch of the duodenum have been removed. The gastro-pancreatic ligament has been divided and is seen limiting, on the left, the recessus medius.

LITERATURE ON LESSER SAC.

1. Erik Müller, *Beiträge zur Anatomie des menschlichen Fetus*, Stockholm, 1897.
2. Ivar Broman, *Normale und abnorme Entwickelung des Menschen*, Wiesbaden, 1911.
3. P. T. Crymble, 'Gastro-pancreatic Folds: their Relation to the Movements of the Stomach, and to the Subdivisions of the Lesser Sac,' *Jour. Anat. and Phys.*, vol. xlvii., 1912–13.

PARIETO-COLIC FOLDS.

The most constant of these folds attaches the splenic flexure to the diaphragm in the region of the tenth rib. It forms a horizontal shelf upon which the spleen may rest, and, when well developed, shows a depth of 7·5 cm., and acts as a barrier to the passage upwards of pathological fluids. It varies considerably in its attachments, position, and extent, and may be entirely absent.

On the right side of the abdomen, the fold is not so constant, and its position is more variable. Thus it may attach the hepatic flexure to the ribs, or the ascending colon to the iliac crest, or the cæcum to the iliac fossa, or it may occupy any intervening position. It may form a mere horizontal shelf, or it may be present in the form of a coronally placed membrane extending from the parietes to the anterior tænia of the ascending colon. When present in this latter form, there is always a fossa lying posterior to the membrane, and this lateral para-colic fossa opens superiorly or inferiorly into the general peritoneal cavity. Occasionally, one finds two fossæ behind the membrane : one opening superiorly and one opening inferiorly.

Although in some cases the parieto-colic fold corresponds closely to the sustentaculum hepatis of Treves, and either supports the liver in adult life, or may have supported the liver in early childhood when that organ was proportionately larger, still, in the majority of cases, the fold is associated with ptosis of the cæcum and has no relation to the liver.

MEDIAN PARA-COLIC FOSSÆ.

In fig. 330, one type of median para-colic fossa is illustrated. A much commoner form is, however, shown in fig. 332, where the ascending colon and the first few

inches of the transverse colon are bound together by a peritoneal sheet. This sheet appears to be part of the great omentum, and posterior to it is a capacious

FIG. 330.—PARIETO-CÆCAL FOLD AT THE LEVEL OF THE ANTERIOR SUPERIOR ILIAC SPINE IN A FEMALE AGED THIRTY-FIVE YEARS, WITH SLIGHT PTOSIS OF CÆCUM. (Crymble and Malcolm.)

Note also the small fold attaching the median aspect of the hepatic flexure to the posterior abdominal wall. A fossa (median para-colic) lies posterior to this fold. This latter fold is very rare, as we have only the one example of it, and it is not mentioned in the literature.

median para-colic fossa containing in this subject a loop of small intestine. We have met with this arrangement in two bodies.

ILEAL FOLDS AND KINKS.

One example of a kink of the pars cæcalis ilei is illustrated in fig. 333, where the right iliac fossa and contents, of a male aged sixty-five years, are seen.

FIG. 331.—MARKED PTOSIS OF CÆCUM AND ASCENDING COLON IN A FEMALE AGED SEVENTY-SIX YEARS, THE CÆCUM LYING IN THE TRUE PELVIS, WITH AN EXTENSIVE PARIETO-COLIC FOLD IN THE REGION OF THE ILIAC CREST. (Crymble and Malcolm.)

The ileum became retro-peritoneal where it crossed the right psoas, passed outwards in the iliac fossa, and made two right-angled bends before joining the

cæcum. The first bend was maintained by a peritoneal ridge running outwards to the iliac crest. It must be borne in mind that normally the ileum passes forwards

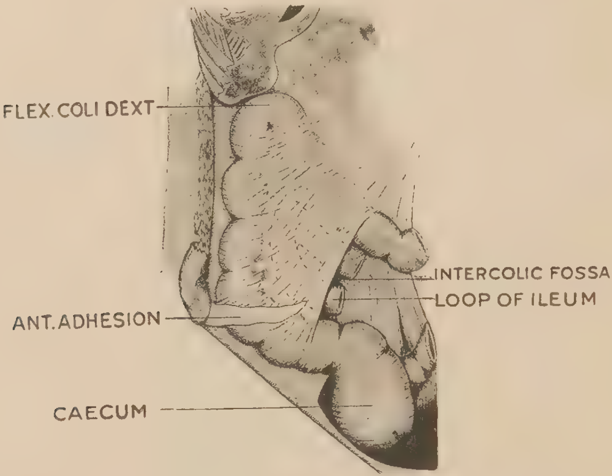


Fig. 332.—Median para-colic fossa, containing a loop of small intestine, in a female aged sixty-seven years, with adhesion between colon and anterior abdominal wall. Coloptosis. (Crymble and Malcolm.)

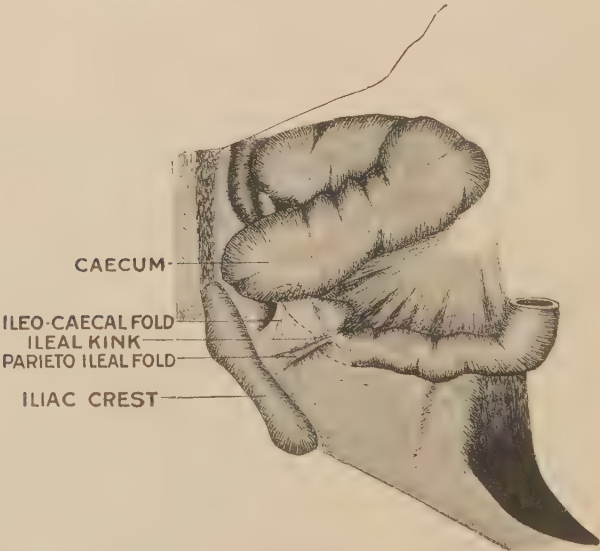


Fig. 333. (Crymble and Malcolm.)

The cæcum has been turned upwards to expose the termination of the ileum. There is a well-marked V-shaped kink: the apex of the V, directed downwards and outwards, being attached to the iliac crest by a ridge-like peritoneal fold. Distal to this kink, the ileum is attached to the iliac fossa by a peritoneal sheet, probably formed by the ileo-cæcal fold; behind this ileo-cæcal fold is a fossa. The portion of the ileum in the iliac fossa proximal to the kink is destitute of a mesentery and is therefore retro-peritoneal.

and upwards from the bottom of the pelvis, along the right pelvic wall, to the ileo-cæcal junction. If this junction lies some distance lateral to the pelvic brim,

the ileum will cross the pelvic brim and pursue a short course in the iliac fossa. Further, the pars cæcalis ilei may possess a mesentery or may be bound down (*i.e.*, retro-peritoneal) to the pelvic wall, the psoas margin, or the iliac fossa. In the latter case, a peritoneal fold is present at the junction of fixed and movable portions, of the same nature, and with a similar mode of production as the fold at the œsophageo-gastric, pyloro-duodenal, or duodeno-jejunal junctions. In short, these folds are all produced by traction, which in the ileum is produced by the

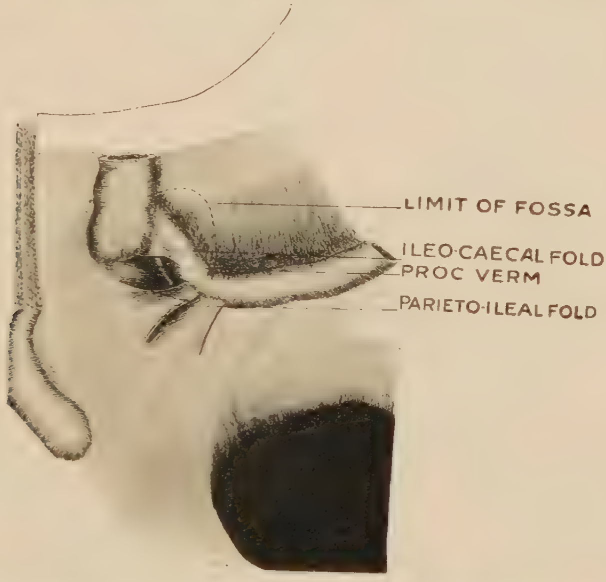


FIG 334.—TERMINATION OF ILEUM AND CÆCUM IN A FEMALE, AGED SIXTY-NINE YEARS, SHOWING PARIETO-ILEAL FOLD. (Crymble and Malcolm.)

The dotted line marks out the limits of a fossa which lay behind the cæcum and ileum. There is a fan-shaped fold connecting the ileum to the iliac fossa. This fold is quite distinct from the ileo-cæcal fold which is seen connecting ileum and cæcum. This fold is evidently the genito-mesenteric fold of Reid (a fold frequently found in the fetus), passing from the back of the mesentery of the small intestine to the brim of the pelvis. Sometimes—as in this case—the ileum becomes adherent to this fold.

alternate filling and emptying of pelvic viscera, the bladder and rectum when full driving the pars cæcalis ilei out of the pelvis. There is no evidence to prove that mere fixation of the ileum in its normal position and course produces any degree of intestinal stasis. In fig. 333, however, the ileum pursues a tortuous course in its fixed position, and here stasis is quite probable. Fig. 334 shows a fold fixing the ileum to the psoas, but if the bowel passes forwards from the bottom of the pelvis no kink would be produced.

FORMATION OF PARA-COLIC FOLDS AND FOSSÆ.

There are three possible modes of formation :—

(*a*) **Congenital.**—The presence of a parieto-colic fold about the level of the highest part of the iliac crest is occasionally seen in the fetus and in the young child. Twelve out of the eighteen cases of sustentaculum hepatis, described by Treves,[1] occurred in children under three years. We have seen in a child a parieto-colic fold supporting a loop or knuckle of ascending colon.

1 'The Anatomy of the Intestinal Canal and Peritoneum in Man,' *Hunterian Lectures*, 1885.

(*b*) **Resulting from ptosis.**—It is quite conceivable that ptosis of the cæcum and colon could by traction convert a horizontal peritoneal shelf into a coronally placed parieto-colic membrane of considerable vertical extent which would bound anteriorly a fossa. Such traction formation is figured in fig. 336.

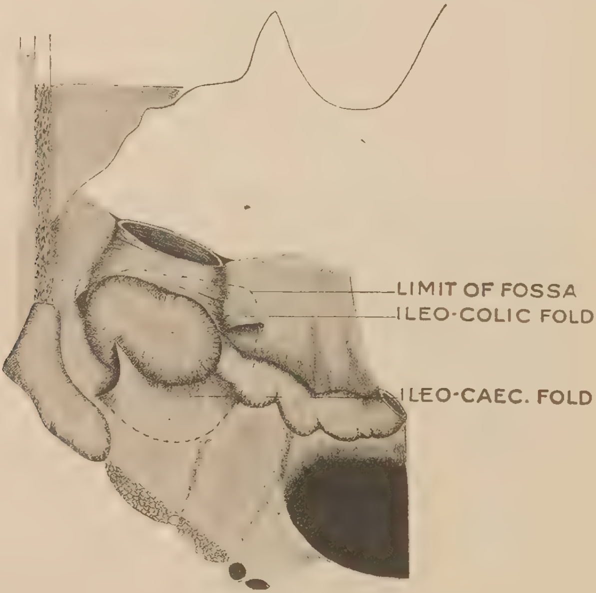


FIG. 335. (Crymble and Malcolm.)

The cæcum has been turned upwards to expose an extensive ileo-cæcal fold which is attached to ileum, cæcum, and iliac fossa. There is a large retro-cæcal fossa containing the vermiform appendix.

Flint[1] explains the coronally placed parieto-colic membrane, occasionally found in the fetus, in a somewhat similar way. Here, however, it is the normal descent of the cæcum which draws out the horizontal shelf into a coronal membrane.

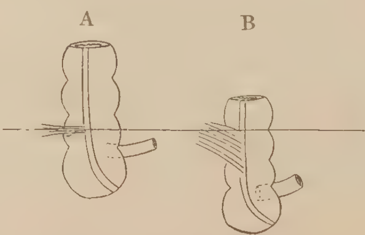


FIG. 336. (Crymble and Malcolm.)

A, normal ascending colon and cæcum, showing a horizontal peritoneal shelf.
B, ptosis of cæcum and colon has dragged the horizontal shelf into a coronal membrane with a fossa, opening inferiorly, behind the membrane.

(*c*) **Inflammatory.**—We believe that some of these folds attached to the cæcum and ascending colon are inflammatory in origin. For example, in fig. 332, there is an adhesion between the anterior abdominal wall and the ascending colon, and the great omentum has attached itself to the ascending colon so as to

[1] Flint, *Johns Hopkins Hosp. Bull.*, September and October, 1912.

form the anterior boundary of a median para-colic fossa. We have never seen this condition in the fetus.

It is, however, quite impossible in most cases to state whether a peritoneal fold or an adhesion is physiological or pathological. Every fetal peritoneal arrangement cannot be accepted as physiological, because the fetus may experience inflammatory changes.

It is without doubt that adhesions may disappear in the fetus and in the adult. According to Broman[1] adhesions in the fetus persist only in the presence of pressure and in the absence of movement.

If we apply the same view to the adult, all the different folds and fossæ can be explained as being the sequelæ of inflammation.

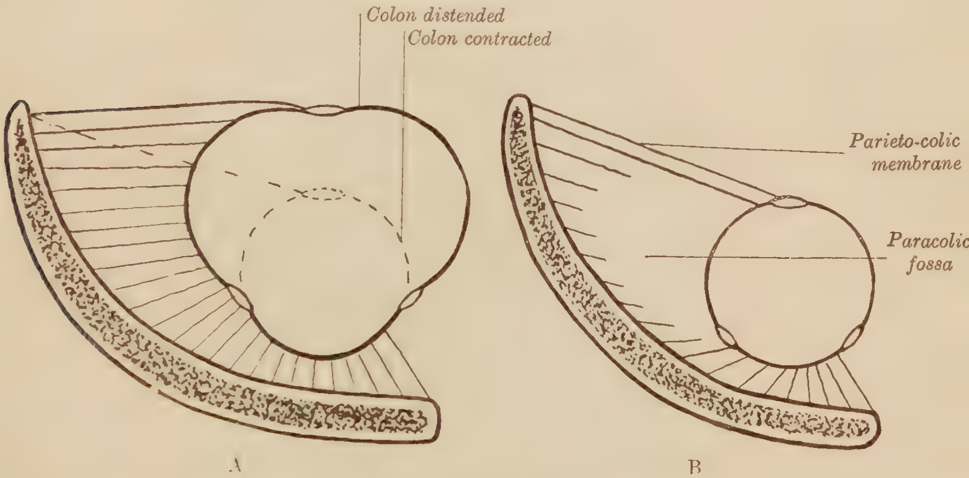


FIG. 337.—HORIZONTAL SECTIONS THROUGH THE RIGHT ILIAC FOSSA, ILLUSTRATING DIAGRAMMATICALLY A POSSIBLE MODE OF PARIETO-COLIC MEMBRANE AND PARA-COLIC FOSSA FORMATION. (Crymble and Malcolm.)

A, condition previous to fossa formation.
B, condition after partial disappearance of adhesions.

Let us suppose a peri-colic inflammation, with temporary adhesions forming between the cæcum, ascending colon, and neighbouring structures—*e.g.*, small intestine, transverse colon, lateral and anterior abdominal walls, great omentum. The adhesions disappear in the parts subjected to most movement. These parts are :

1. **The median aspect of the ascending colon and cæcum between the anterior and postero-median tæniæ.**—This part is exposed to movements of small intestine and transverse colon, and experiences marked alterations in its own form through peristalsis. The anterior tænia remains comparatively at rest, and therefore to it the great omentum remains attached. Thus arises the median para-colic fossa of fig. 332.

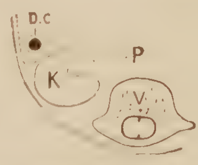


FIG. 338.—TRANSVERSE SECTION THROUGH THE ABDOMEN OF A FETUS 8·3 CM. (J. Symington).

V, body of lumbar vertebra; K, left kidney; D.C., descending colon; P, peritoneum.

2. **The lateral aspect of the ascending colon above the iliac crest and between the anterior and postero-external tæniæ.**—This part is exposed to movements in the lateral muscular

[1] Ivar Broman, *op cit.*, p. 354.

abdominal wall, and to the dilatation, contraction, and peristalsis of its own musculature. It is therefore much rarer to find parieto-colic folds in this region than in the iliac fossa where the postero-lateral abdominal wall displays no movement. Note figs. 330, and 331 where the folds do not extend above the iliac crest.

3. **The lateral aspect of the cæcum and iliac portion of ascending colon.**—This is the commonest seat of folds and fossæ, because this part is not exposed to a moving abdominal wall, nor to the movements of other viscera, but

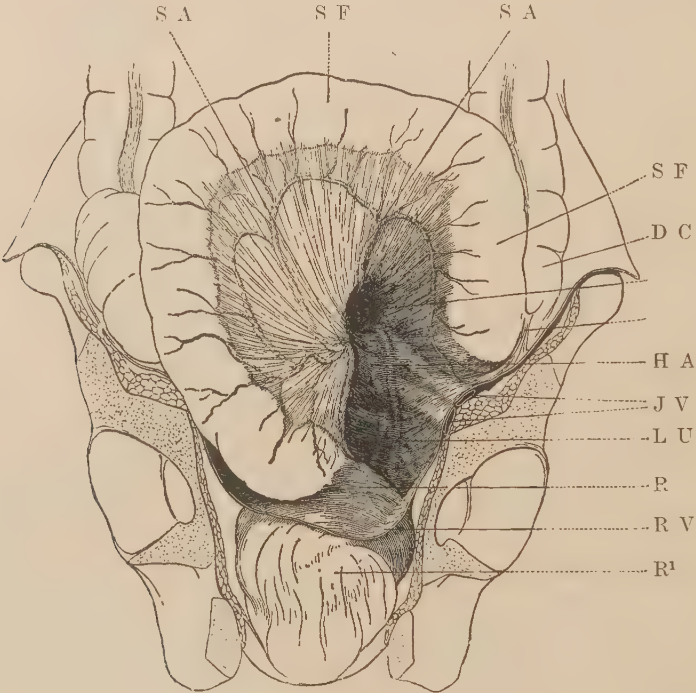


Fig. 339.—View of inter-sigmoid fossa. (Jonnesco.)

The pelvis has been divided in a coronal plane opposite the bottom of the recto-vesical pouch, and the sigmoid loop (pelvic colon) has been turned upwards and to the right.

D. C., descending colon; S. F., sigmoid colon; R., rectum covered by peritoneum; R[1], rectum uncovered by peritoneum; R. V., recto-vesical fold of the peritoneum; S. A., branches of the sigmoid artery; L. U., left ureter; I. V., external iliac artery and vein; H. A., ligamentum umbilicalis lateralis.

experiences only its own intrinsic movements. It is these intrinsic movements of dilatation and contraction which account for the lateral para-colic and para-cæcal fossæ. Let us suppose an adhesion between this part of the bowel and the iliac fossa. During contraction and dilatation, the tæniæ will remain as more or less fixed points, whereas most movement will be experienced by the bowel wall midway between the tæniæ. At the seat of this marked movement, the adhesions disappear and a fossa results, leaving a membrane attaching the anterior tænia to the iliac fossa (fig. 337).

PERITONEAL FOSSÆ.

Peritoneal fossæ or pouches are often found on the posterior wall of the abdomen. They are of importance surgically on account of the fact that portions

of the intestine are liable to become lodged in them, giving rise to retro-peritoneal herniæ.

Several of these fossæ are found in relation with the cæcum, and have already been described (see p. 114). Another fossa, the *inter-sigmoid*, is very commonly met with during the fifth and sixth months of fetal life. This recess is funnel-shaped and opens below, behind the root of the mesentery of the pelvic colon. It extends upwards for a variable distance along the course of the ureter. In the young fetus (see fig. 338), the descending colon is connected by a relatively long mesentery to the posterior abdominal wall near the median plane. The posterior layer of the descending meso-colon soon unites with the peritoneum in front of the

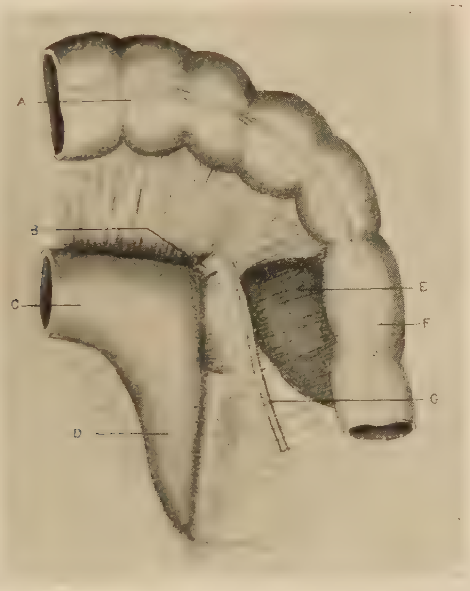


FIG. 340.—A PLICA DUODENO-JEJUNALIS OF SMALL EXTENT. (P. T. Crymble.)

The transverse colon has been thrown upwards, and the small intestine has been thrown to the right. A plica duodeno-jejunalis of small extent is exposed. A, transverse colon ; B, plica duodeno-jejunalis ; C, jejunum ; D, pars ascendens duodeni ; E, left kidney ; F, descending colon ; G, inferior mesenteric vein.

kidney ; but internal to this organ, the fusion of the two layers of peritoneum does not occur so readily, hence the formation of a tubular recess, which communicates below with the general peritoneal cavity. This fossa is only occasionally met with in a well-developed condition in the adult. Several fossæ, duodenal and duodeno-jejunal, are sometimes present near the termination of the duodenum. According to Jonnesco (Poirier's 'Traité d'Anatomie humaine,' vol. iv., pp. 256–263), there are five varieties of fossæ met with in this region : namely, *inferior duodenal, superior duodenal, retro-duodenal, para-duodenal*, and *duodeno-jejunal*.

The **plica duodeno-jejunalis** is a useful guide to the surgeon in locating the duodeno-jejunal flexure. Two types of this fold are found :—

1. The plica connects the summit of the flexure to the posterior abdominal wall immediately inferior to the body of the pancreas. It does not extend to the left of the inferior mesenteric vein, and it accurately surrounds the musculus suspensorius duodeni (fig. 340).

2. The plica, more extensive than in the previous type, connects the summit of the flexure to the posterior abdominal wall and the anti-mesenteric border of the

first one or one and a half inches of the jejunum to the posterior surface of the transverse meso-colon. It extends to the left of the inferior mesenteric vein, and the musculus suspensorius duodeni is enclosed only by its median portion (figs. 341 and 342).

The **superior duodenal fossa** lies to the left of the ascending portion of the duodenum, near its termination. The orifice looks downwards and the fossa, bounded in front by the superior duodenal fold, extends upwards to the body of the pancreas. The inferior duodenal fossa lies to the left of the ascending portion of the duodenum, being bounded anteriorly by the inferior duodenal fold. The fossa extends downwards and to the right, and opens superiorly.

The **retro-duodenal fossa** lies behind the horizontal and ascending

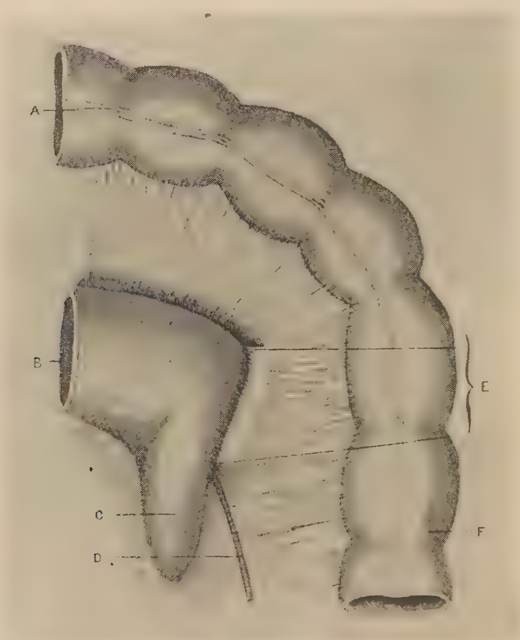


Fig. 341.—Extensive plica duodeno-jejunalis. (P. T. Crymble.)

The transverse colon has been thrown upwards and the small intestine has been turned to the right. A plica of Type 2 is exposed. A, transverse colon; B, jejunum; C, pars asc. duod.; D, inferior mesenteric vein; E, plica duodeno-jejunalis; F, descending colon.

portion of the duodenum and in front of the aorta. It opens inferiorly, and is bounded laterally by two duodeno-parietal folds. In depth, the fossa varies from 7 cm. to 9 cm.

The **para-duodenal fossa** lies to the left of and some distance from the ascending portion of the duodenum, and is bounded anteriorly and laterally by a fold of peritoneum raised from the posterior abdominal wall by the inferior mesenteric vein, which partially encircles the orifice of the fossa. The orifice is wide, and looks downwards and to the right.

The **duodeno-jejunal fossa** is exposed, when present, by dragging the transverse colon upwards, and the jejunum downwards and to the right. It is situated at the root of the meso-colon, contains the duodeno-jejunal flexure and is bounded on either side by a duodeno-meso-colic fold.

ABNORMAL ARRANGEMENT OF PERITONEUM.

Various abnormal folds of peritoneum are found in connexion with the different parts of the colon. Those in relation to the cæcum and ascending colon have already been described, and there remain to be noted those affecting the transverse and pelvic colons.

1. The first part of the transverse colon may be closely adherent to the anterior surface of the ascending colon, a kink at the hepatic flexure being produced.

2. A portion of the transverse colon may form a U-shaped loop, the two limbs of the loop being closely united (fig. 344).

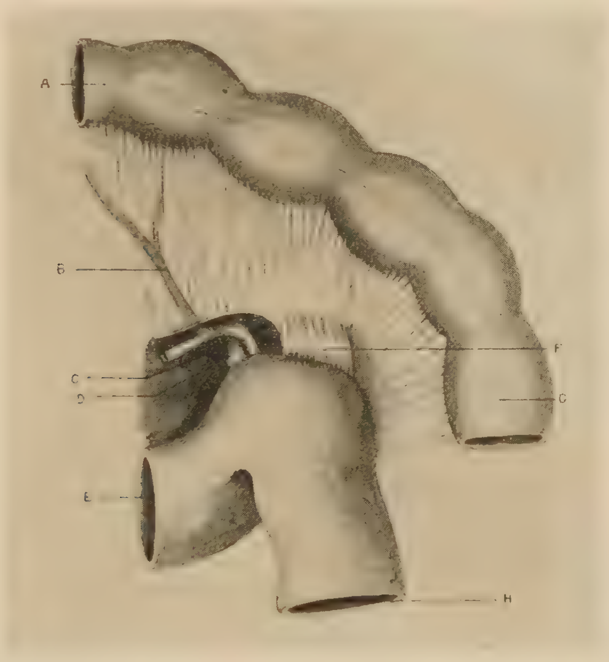


FIG. 342.—ILLUSTRATION OF AN EXTENSIVE PLICA DUODENO-JEJUNALIS. (P. T. Crymble.)

An extensive plica of Type 2 is present, but the musculus suspensorius duodeni is very small. Note that the latter structure is sharply limited laterally by the inferior mesenteric vein. (This relation is always present.) A communication between the middle colic and inferior mesenteric veins is present. A, transverse colon; B, middle colic vein; C, inferior mesenteric vein; D, muscle of Treitz; E, duodenum; F, plica duodeno-jejunalis; G, descending colon; H, jejunum.

3. The apex of a U-shaped loop of transverse colon may be fixed to the hepatic flexure, a triple-barrelled arrangement being thus formed (fig. 343).

4. The transverse colon may be fixed in a position anterior to the liver (fig. 345).

5. The distal third or fourth of the transverse colon may be fixed by a short fold to the left iliac fossa and posterior abdominal wall, median to the descending colon (fig. 346). This arrangement of peritoneum produces a striking alteration in the position of the small intestine. Normally, the small intestine lies in the left ilio-lumbar and pelvic regions, with occasionally some inches in the right ilio-lumbar region. This abnormal fixation of the colon prevents the small intestine entering the left ilio-lumbar region, and forces it to take up a position in front of the cæcum and ascending colon (fig. 347).

6. The pelvic colon may form a U-shaped loop with the bowel entering and leaving the loop closely united by adhesions (fig. 343), or with the two limbs of the loop closely united to each other and to the descending and iliac colons (fig. 348).

Fig. 343.—Abnormal arrangement of the transverse and pelvic colons. (P. T. Crymble.)

The apex of a loop of transverse colon was fixed to the hepatic flexure. The loop and the proximal few inches of the transverse colon forming a closely united triple-barrelled arrangement. Three well-marked angulations were present (see arrows). The limbs of a loop-shaped pelvic colon were closely united at the base of the loop.

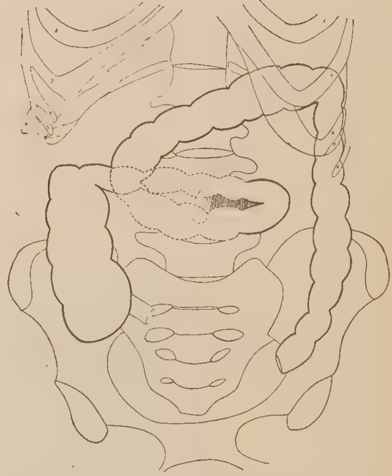


Fig. 344.—Abnormal arrangement of the transverse meso-colon. (P. T. Crymble.)

Shows a loop of transverse colon disposed horizontally and lying behind coils of jejuno-ileum. The two limbs near the apex of the loop are united by a close adhesion, and the apex lay superficially.

Fig. 345.—Abnormal peritoneal relation of the transverse colon. (P. T. Crymble.)

A loop of transverse colon occupies the right anterior intraperitoneal sub-phrenic space and is fixed in this position by adhesions to the liver.

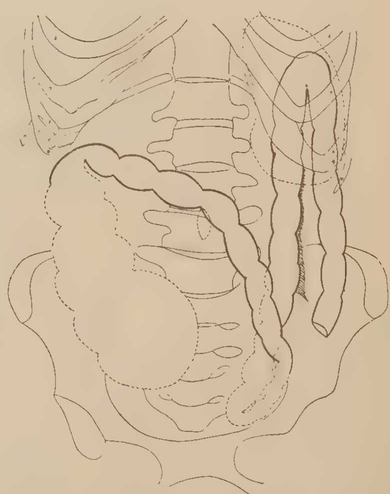


Fig. 346.—Abnormal arrangement of peritoneum. (P. T. Crymble.)

The transverse colon forms a long V-shaped loop, the apex of which lies in the pelvis. The distal third of the transverse colon is adherent to the posterior abdominal wall. This arrangement of colon prevented the entrance of small intestine into the left ilio-lumbar region, and resulted in the cæcum and ascending colon being covered by small intestine.

7. In fig. 349, the transverse colon passes below the root of the mesentery and behind the coils of small intestine, and is fixed in this position by adhesion to the posterior abdominal wall. The upper region of the abdomen is completely shut off from the lower region by a peritoneal membrane attaching the proximal fourth of the transverse colon and the great curvature of the stomach to the anterior abdominal wall, and the peritoneal cavity of this lower region passes freely upwards behind the stomach, where it is separated from the bursa omenti minoris by a complete septum bursarum composed of gastro-phrenic and gastro-pancreatic folds.

The bursa omentis minoris, and the peritoneal cavity in relation to the liver, is normal. A gastro-splenic ligament is present, but it has no connexion with the peritoneal diaphragm above described, and it shows a free lower border.

There are two possible explanations of this condition :—

1. That the colon rotation has not taken place in the usual manner, and adhesion between the transverse colon and the posterior wall of the lesser sac has been prevented by the coils of small intestine. The lower part of the lesser sac has been invaginated into the gastric recess.

2. The small intestine has burst through the transverse meso-colon, entered the lesser sac, and then burst through the great omentum, thus forming a free communication between the great sac and the gastric recess.

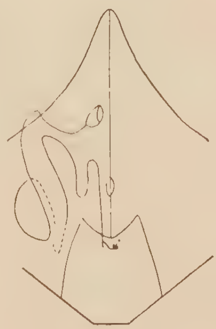


FIG. 347.—ABNORMAL POSITION OF SMALL INTESTINE. (P. T. Crymble.)

Shows the arrangement of the small intestine in the right ilio-lumbar region of the case illustrated in fig. 346. The small intestine occupied the right ilio-lumbar and pelvic regions. The pelvic loops were too complicated to figure. There was no small intestine in the left ilio-lumbar region.

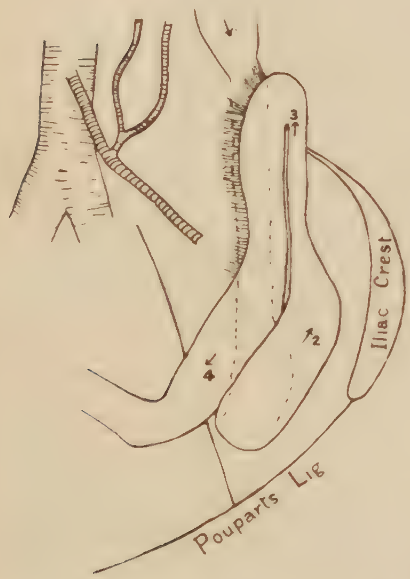


FIG. 348.—ABNORMAL ARRANGEMENT OF THE PERITONEUM IN RELATION TO THE PELVIC COLON. (P. T. Crymble.)

The pelvic colon formed a ∩-shaped loop and occupied the left ilio-lumbar region. The two limbs of the loop were closely adherent to each other and to the descending and iliac colons. This arrangement was present in two elderly female subjects which were dissected in the Anatomy Department of Queen's University, Belfast, Session 1909–10. The abdomens were quite free from other adhesions and there was no macroscopic evidence of obstruction.

APPLIED ANATOMY.

The peritoneum is liable to infection from the viscera in its neighbourhood. The fluid poured out by inflamed peritoneum or by a diseased viscus is controlled by gravity, by the arrangement of the peritoneum, and by the formation of peritoneal adhesions.

The three most dependent parts of the peritoneal cavity, with the body supine, are the pelvic cavity and the kidney pouches, and fluid therefore tends to collect in one or more of these parts. Certain regions have a peritoneal arrangement which readily permits of complete isolation by adhesions—*e.g.*, the lesser sac requires only the obliteration of the foramen of Winslow ; and the sub-phrenic region, or one of its subdivisions, may be isolated by an adhesion between the transverse colon or omentum and the anterior and lateral abdominal walls.

The following are the common causes of abscess of the various parts of the peritoneal cavity :—

a. The right anterior intraperitoneal is usually infected by a liver abscess or a right pleural empyema.

b. The right posterior intraperitoneal is infected by inflammation of the gall-bladder, by perforation of a gastric or duodenal ulcer, or by appendicitis. In the latter case, the pus passes upwards, lateral to the ascending colon. The gall-bladder, stomach, and duodenum are contents of the space.

c. The left anterior intraperitoneal is infected by a left pleural empyema, a perforated gastric ulcer, or an appendicitis. In the latter case, the pus passes from the pelvis, where it has collected, upwards, being guided to the space by the mesentery or by the lateral surface of the iliac and descending colon.

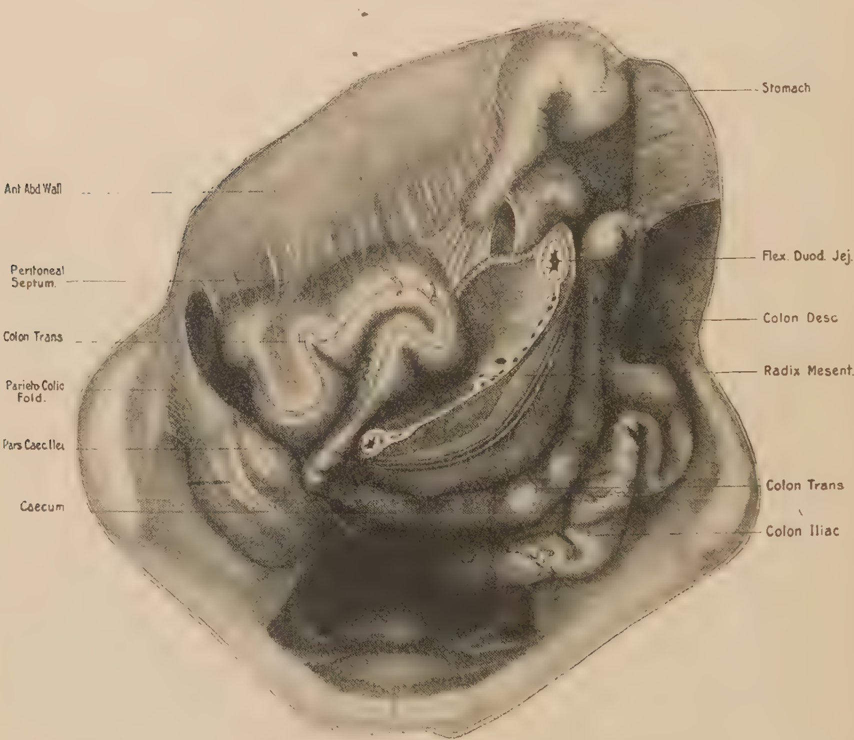


Fig. 349.—Abnormal arrangement of peritoneum and transverse colon. (P. T. Crymble.)

The transverse colon passed below the root of the mesentery and behind the jejuno-ileum. Throughout its whole course it was closely adherent to the posterior abdominal wall or to viscera lying on the posterior abdominal wall. The left ilio-lumbar region communicates freely with a retro-gastric space. The small intestine occupied the retro-gastric space, the left ilio-lumbar region, and the pelvic cavity.

d. The left posterior intraperitoneal space or lesser sac is infected by lymphadenitis of superior pancreatic glands, by pancreatitis, or by perforation of the posterior stomach wall.

e. The right ilio-lumbar space is usually infected by the vermiform appendix.

f. The left ilio-lumbar space may be infected by perforation of the jejuno-ileum—most frequently the lower two feet of ileum, in typhoid fever—or by pericolitis sinistra.

g. The pelvic cavity is more frequently infected in the female, owing to the frequency of inflammation of the uterine tubes. Owing to its dependent

position, fluid from any perforated viscus tends to collect here, and inflammation of a vermiform appendix directed towards the pelvis readily infects the space.

MOVEMENTS OF THE OMENTUM.

J. E. Adams (*Lancet*, March 8, 1913), by attaching lead pellets to the border of the omentum and examining by the X-rays, found that the movement was slight and appeared to be secondary to intestinal peristalsis.

SENSIBILITY OF THE PERITONEUM.

Carl Franke (*Berl. klin. Woch.* Oct. 14, 1912) discusses the sensitiveness of the abdominal viscera. These viscera are innervated by the vagi, the sacral autonome, and the sympathetic ; but they contain no sensory fibres. Pain in an abdominal organ is due to stimulation of ordinary spinal nerves, issuing from the posterior spinal roots.

In the human subject. the experience of local anæsthetics permits of a number of deductions. The parietal peritoneum is extremely sensitive, and has the power of localisation to some extent. Pain is felt in the mesentery right up to the intestine. The liver, apart from its peritoneal covering, is insensitive. The gastro-intestinal canal is insensitive : the pain of intestinal colic being due to dragging on the mesentery, and the pain of biliary colic being due to dragging on the nerves at the neck of the gall-bladder.

For further information on the peritoneum, consult :—

1. Moynihan, *Retro-peritoneal Hernia.* London, 1899.
2. G. S. Huntington, *Human Peritoneum.* Philadelphia, 1903.
3. D. G. Reid, *Journal of Anatomy and Physiology*, vol. xlvi., 1911–12.
4. P. T. Crymble. 'The Muscle of Treitz and the Plica Duodeno-Jejunalis, *British Medical Journal*, Oct. 15, 1910
5. Crymble and Malcolm, 'Para-colic Folds and Fossæ,' *Transactions of the Ulster Medical Society*, 1912–13.

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